AGRICULTURAL ENGINEERING

MAY • 1952

Labor Requirements for Sprinkler Irrigation of Corn *M. W. Bittinger and R. K. Frevert*

Hydraulic Capacity for Control of Farm Implements *W. H. Worthington and J. W. Seiple*

Relating Basic Resources to Research in Irrigation Agriculture *George D. Clyde*

The Use of Soil Porosity for the Conservation of Water *Lloyd L. Harrold*

Loafing Barns Designed for Summer Temperature Control *G. L. Nelson and E. R. Berousek*

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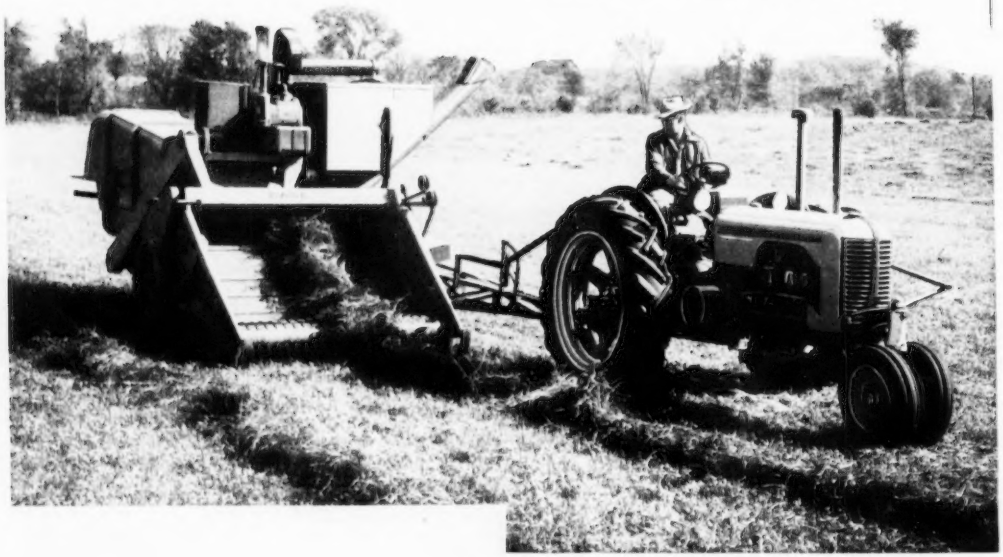

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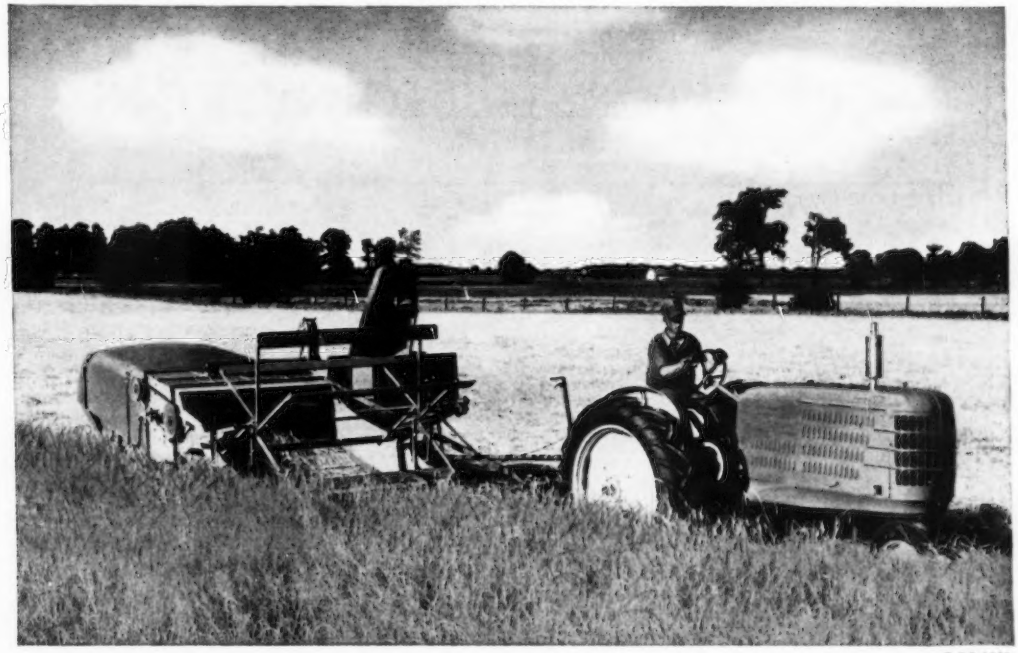

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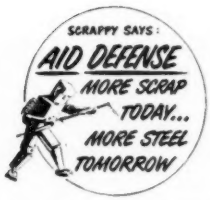

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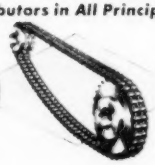
DIAMOND  ROLLER CHAINS

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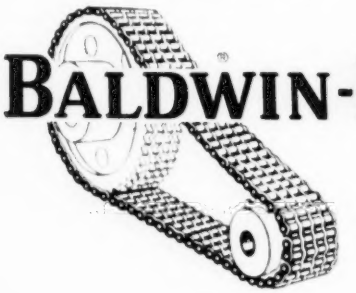

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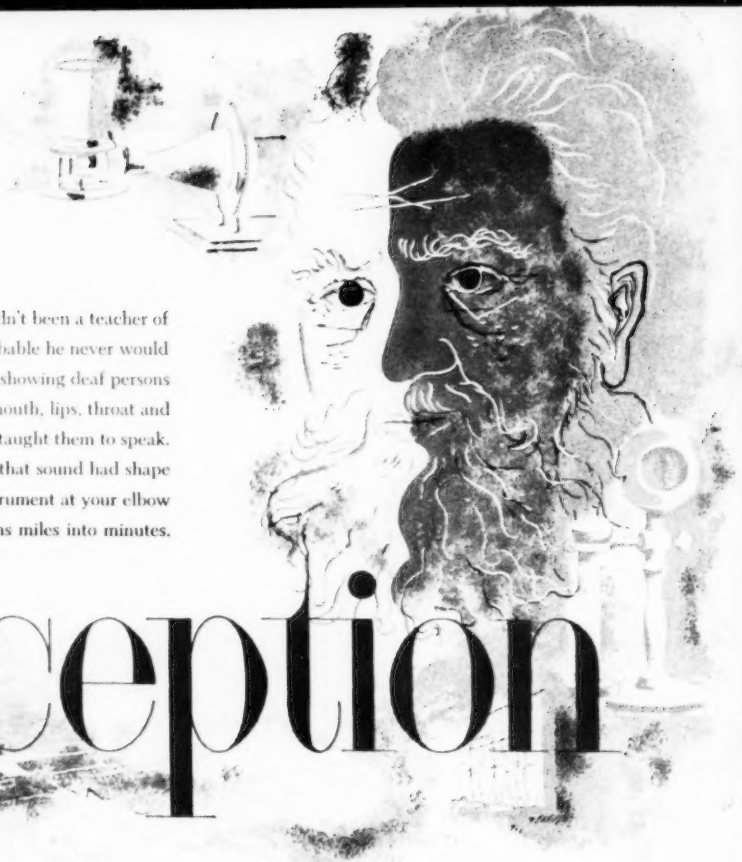

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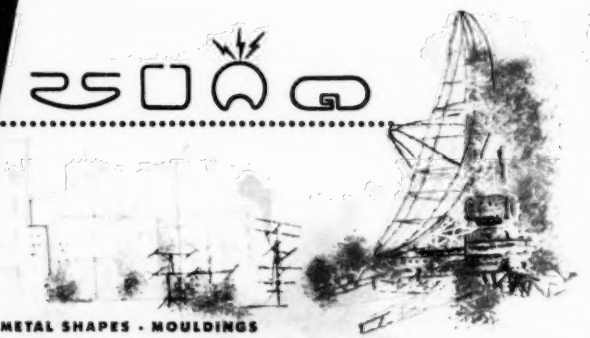

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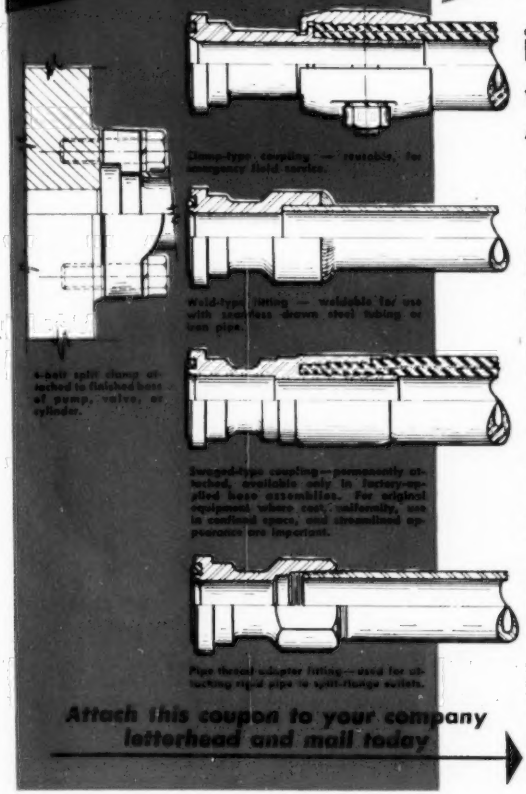

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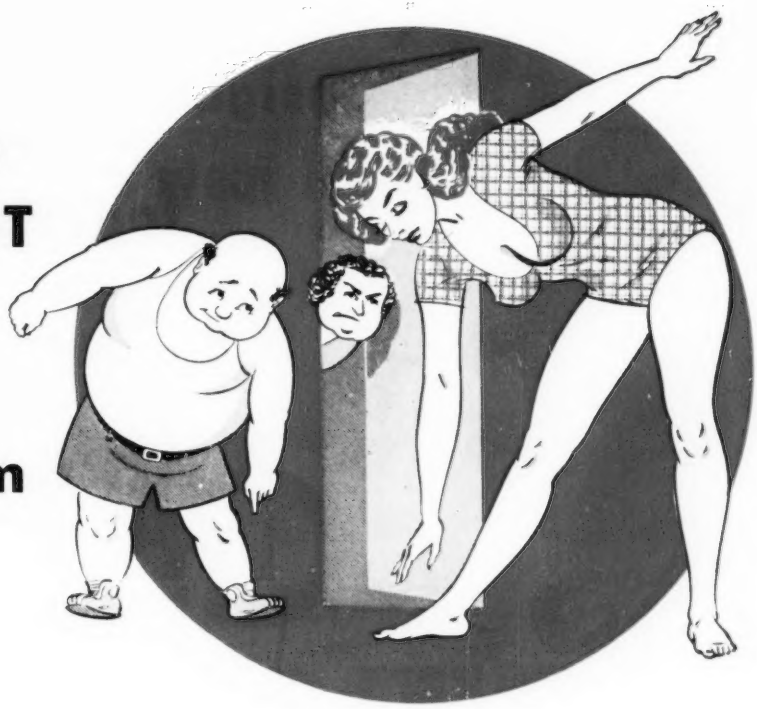

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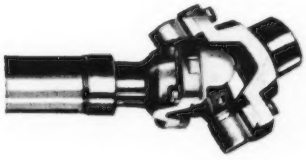

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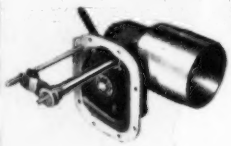

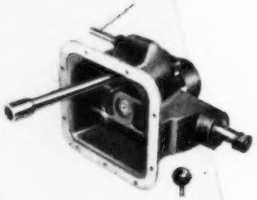

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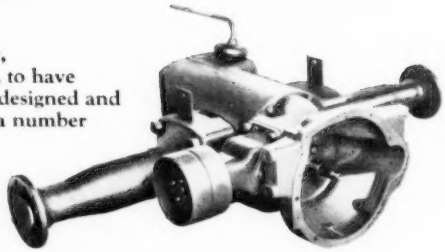

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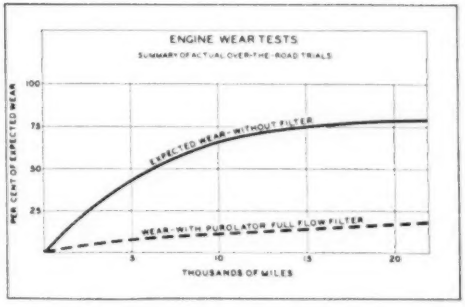

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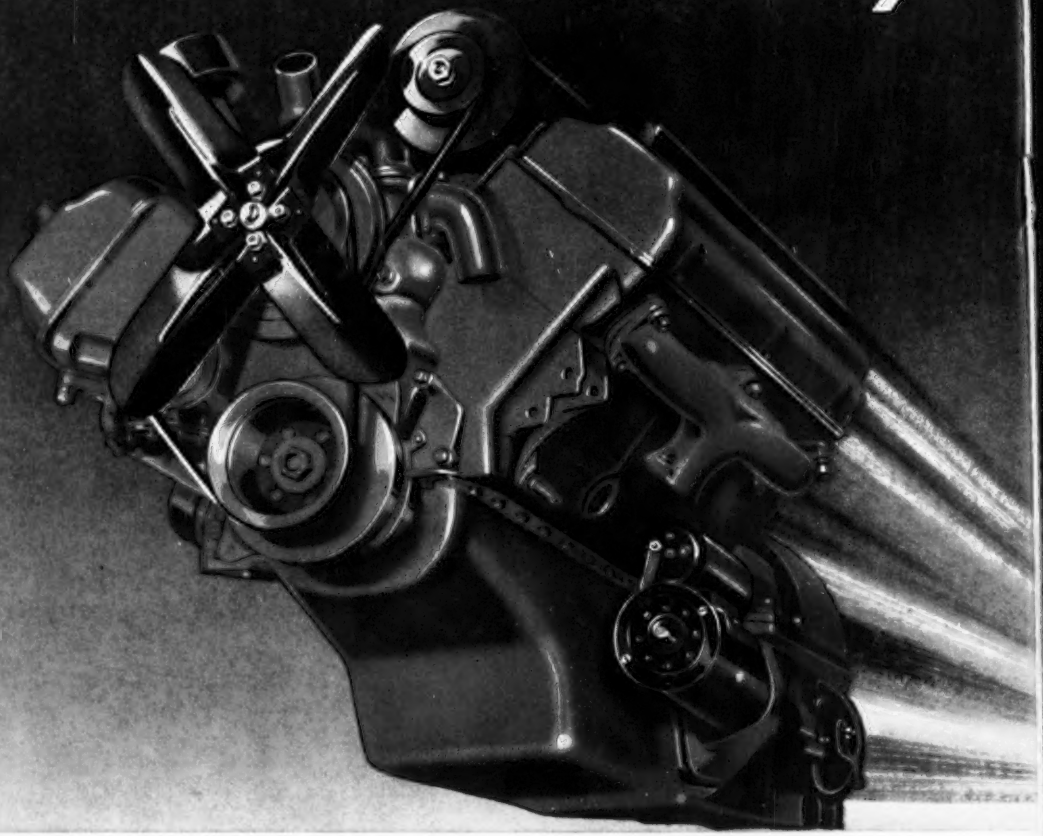

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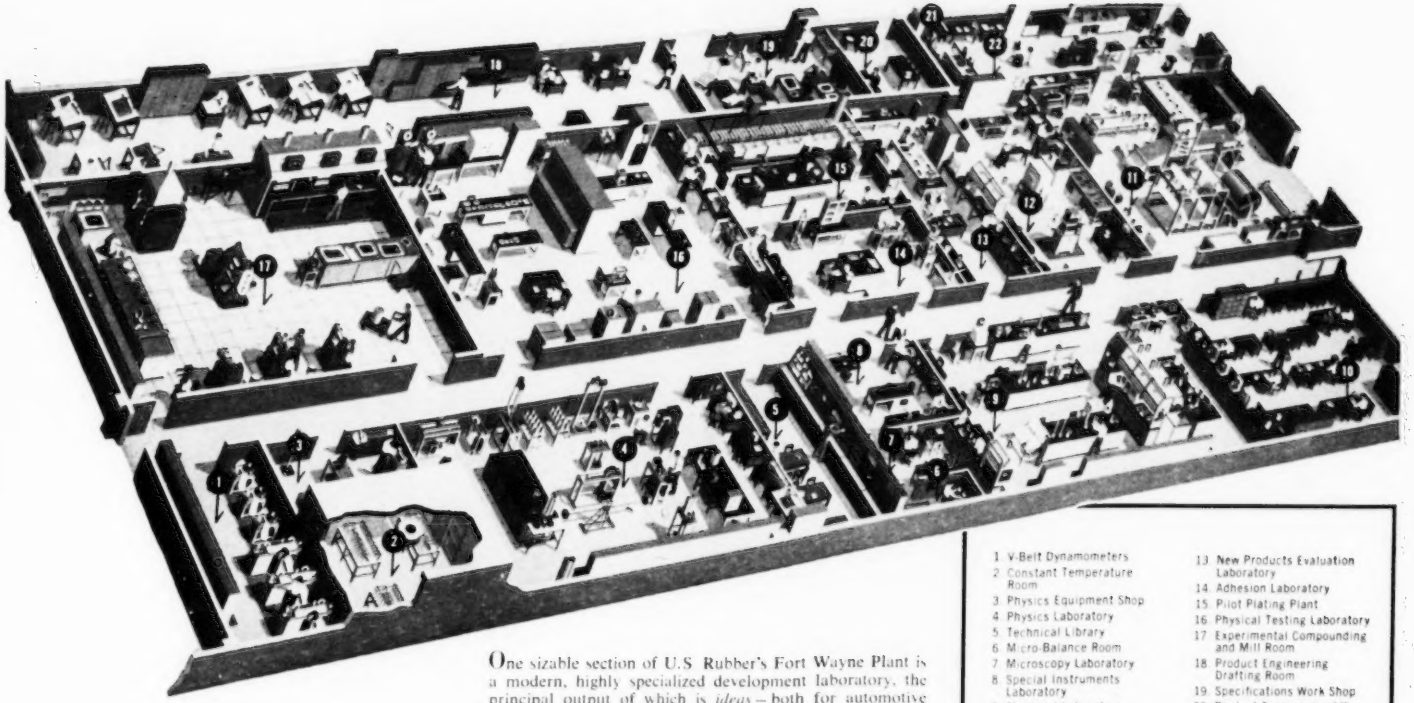

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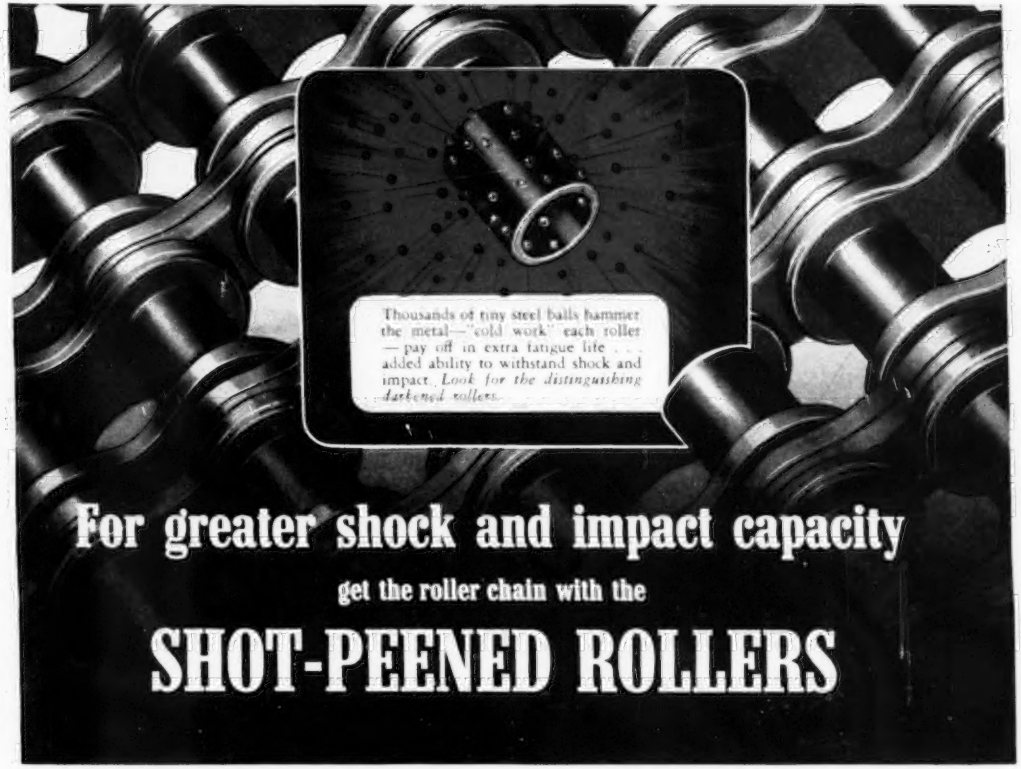
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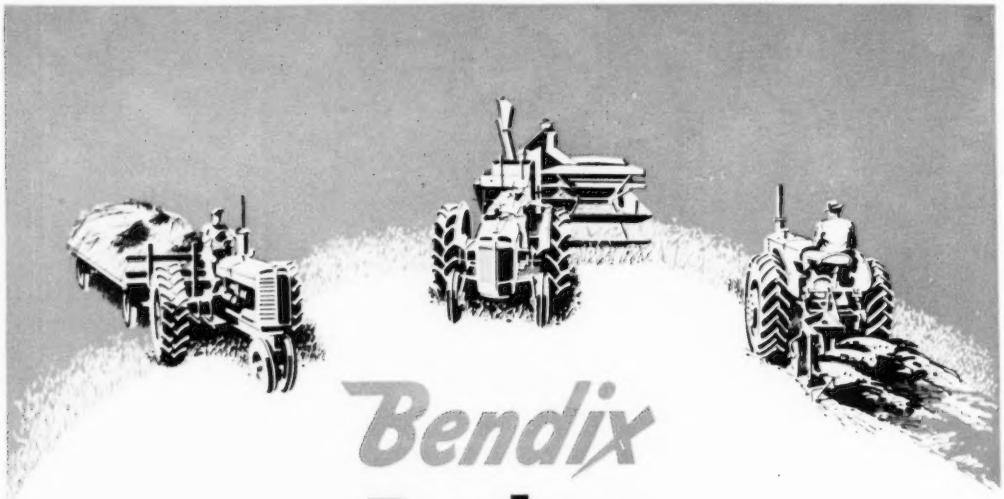

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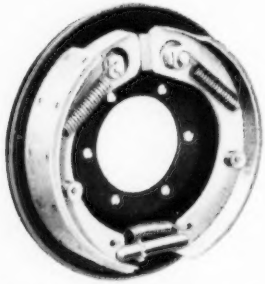

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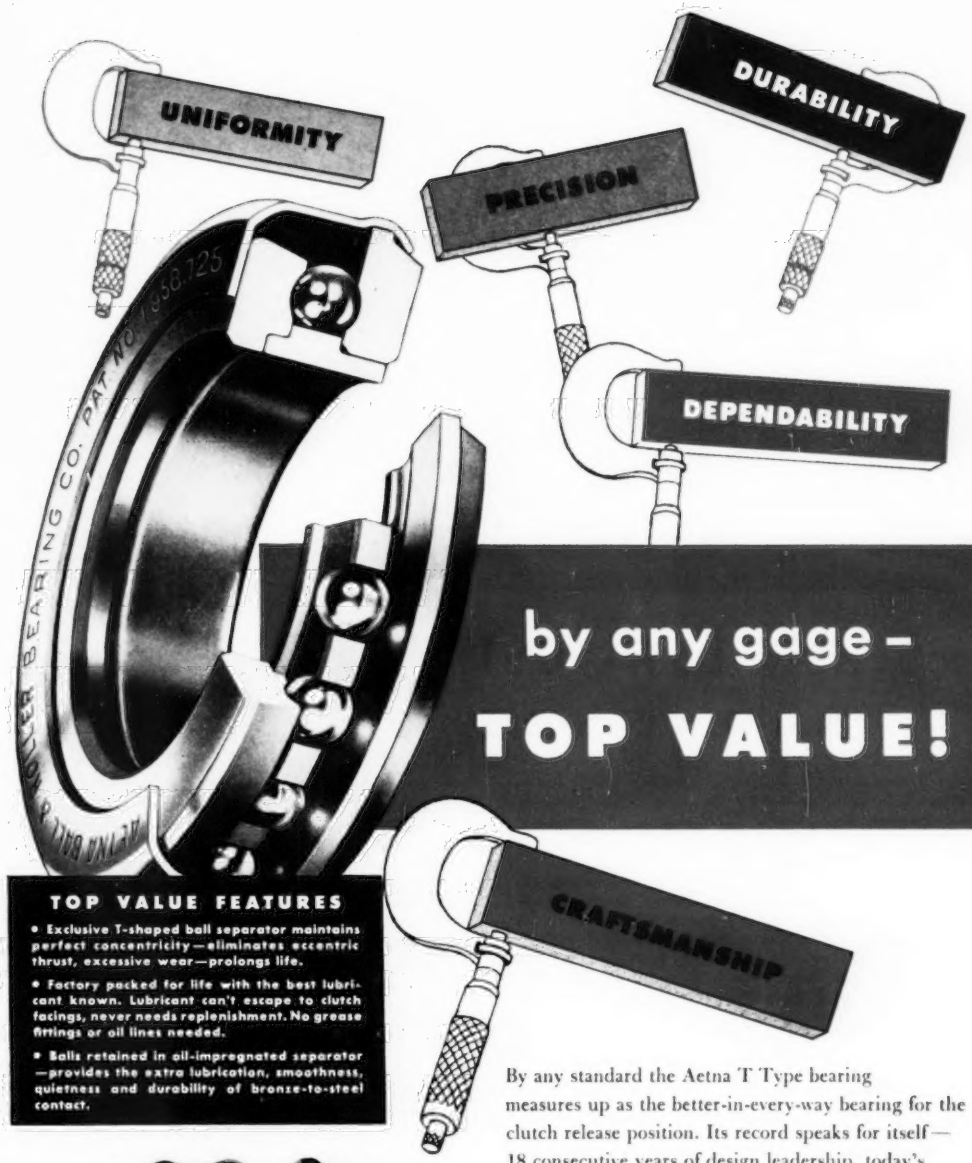

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Thermopane is the easiest way to insulate windows. *Thermopane* is sold by glass and building supply distributors and dealers.

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"IMPROVED FARM BUILDING DAYLIGHTING"

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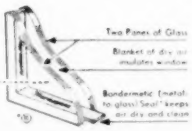
LOOK FOR THE NAME ON THE SEAL BETWEEN THE PANES



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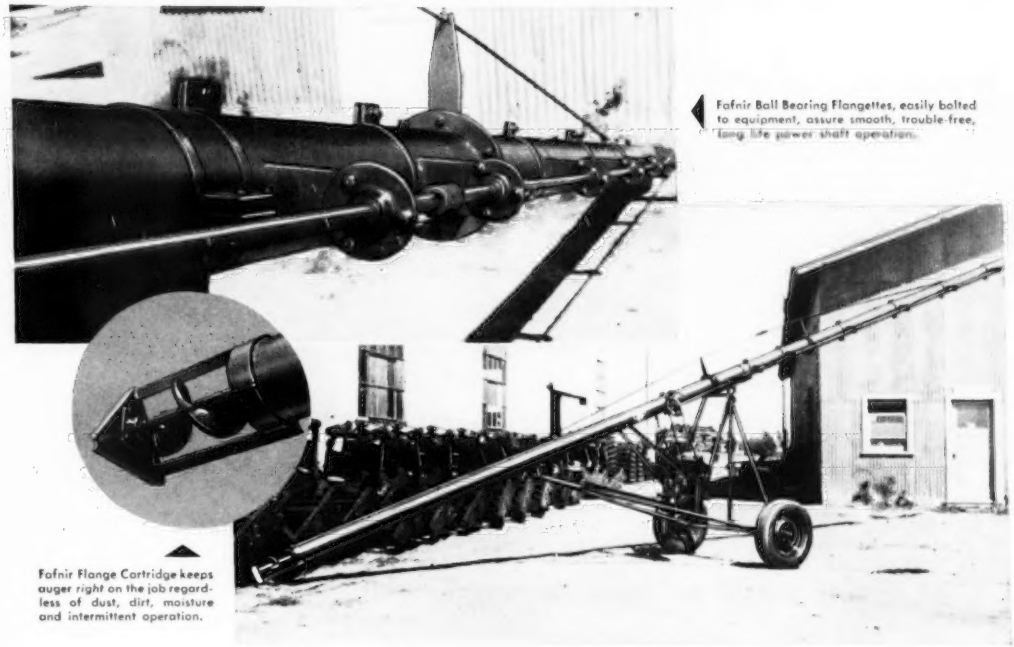
Look outside for the **"inside story"** *of this Grain Auger's* **advanced designing**



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Fafnir Flange Cartridge keeps auger *right* on the job regardless of dust, dirt, moisture and intermittent operation.

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These Fafnir Ball Bearing Units feature the famous Fafnir Wide Inner Ring Bearing with Self-Locking Collar . . . easiest of all to install. Bearings have Fafnir-developed Mechani-Seals which positively keep lubricant in . . . contaminants out.

Like other leading manufacturers of farm equipment, the Blackwelder Mfg. Company, makers of the grain auger, have used Fafnir Ball Bearings to good advantage. But there's more than just good bearings involved in this application . . . it's the Fafnir attitude and aptitude . . . a way of looking at ball bearings from the designer's viewpoint and an aptitude gained from over 40 years' specialization in ball bearings. The Fafnir Bearing Company, New Britain, Connecticut.

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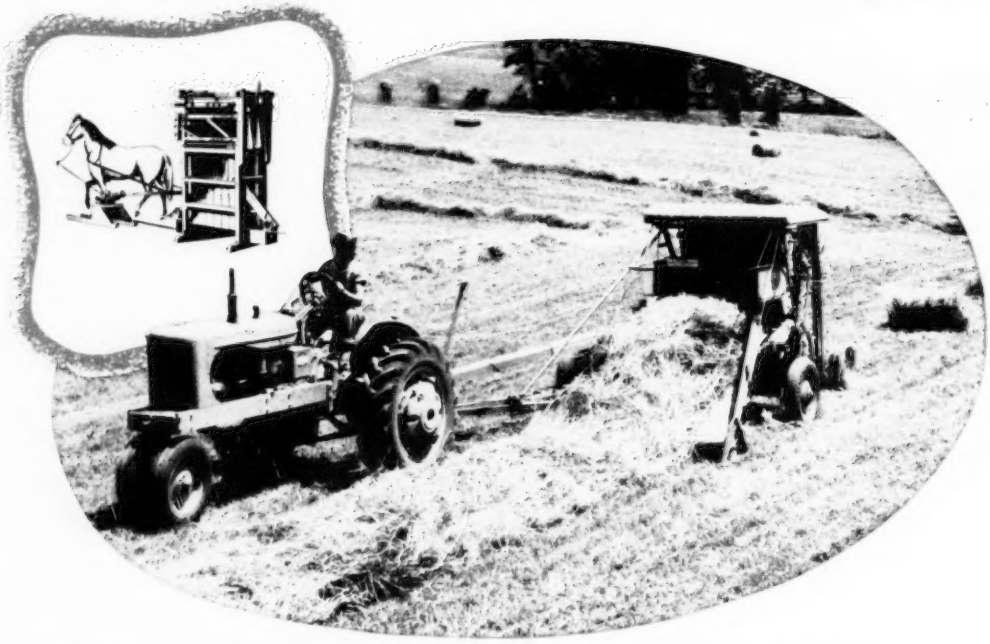

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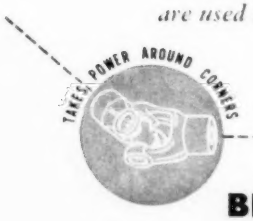
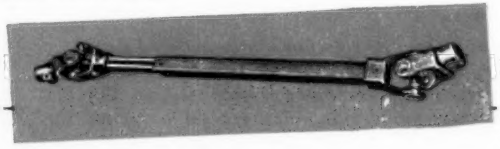
BLOOD BROTHERS Universal Joints

A far cry from the strenuous methods of the 1850's, today's modern baling machines free the farmer from the limitations of muscle power. And from fast implements like this ROTO-BALER — a product of Allis-Chalmers — the farmer gets better bales at far lower cost.

On this and scores of other implements, Blood Brothers Universal Joints help speed progress . . . by delivering flexible power to do old jobs in new, better ways.

For farm implements, more Blood Brothers Universal Joints are used than all other makes combined.





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EDITORIAL

Increasing Farm Productivity

SOME noteworthy new wording on the job ahead of agricultural engineers was recently provided by C. L. Oheim, vice-president of Deere and Company, in addressing a meeting of the Iowa-Illinois Section of the ASAE.

Speaking on the subject "The Labor-Food Production Ratio," he pointed out the need of increased productivity and said in part that "increase in agricultural production per farm worker must come through better farming with more machinery, better machinery, more and better fertilizers, better weed and pest controls, better soil practices and more productive strains of plants and animals.

"Much responsibility for all of these rests on the farm machinery industry. Upon the engineers, who must foresee these changes in the light of new productive materials and methods, the responsibility is especially heavy."

Progressively increasing values are being placed on human life and material well-being. Engineers have no monopoly on this line of thought. It springs from the fundamental instinct for self-preservation. It is fed by a growing realization that higher levels of material well-being are a practical possibility being achieved by increased productivity by some individuals, groups and whole populations to a much greater extent than by others. It matures into a realization that high productivity in supplying human food is basic to high productivity and high levels of material well being in other matters.

What engineers do have is a means of increasing productivity to match and meet the demands of this new readiness for cultural progress. It is the engineering method of patient, matter-of-fact dealing with physical realities.

It has proven its merit in manufacturing, transportation, communications, and other productive activities. It has proven its merit as applied to the somewhat more complex and recently recognized physical realities of agriculture.

It has supported the progressive, optimistic engineering view that we are just beginning to recognize and utilize the physical realities of our environment, and their infinitely complex interrelationships. It supports the idea that agricultural productivity need not be the limiting factor in human progress.

Increasing public recognition that agricultural productivity does involve complex physical relationships best studied and developed by engineering methods is an encouraging sign. It can assure to agricultural engineers the opportunity to work effectively in endeavoring to measure up to their responsibility, as stated by Mr. Oheim.

Engineering in Management

ACCORDING to a recent survey of engineering-management communications,* "a substantial proportion of firms engaged chiefly in engineering design and manufacturing reported that engineering is a fully integrated part of management thinking, and as such engineers participate in management long-range planning as a matter of course."

It appears that this policy might be an important factor in the continuing success of the employing organizations. In that and more direct ways it may also represent to many young engineers a situation favorable to personal and professional development and satisfying careers.

The survey further showed wide variations between individual companies in the extent to which top management values and provides for effective communications with their engineers other than the chief engineer.

These differences in the outlook of top managment, as to the management responsibilities of engineers, are something to be considered by young engineers currently facing a choice between several job opportunities.

Matters on which alert managements are inviting the opinions of their project engineers and engineering staff include product design, production, sales, and customer services, as well as strictly engineering subjects. Project engineers and other engineering staff members contribute to management planning to a significant extent in connection with new products and processes, employee training, purchasing, and plans for expansion, as well as in strictly engineering matters. To a lesser extent they are even contributing to management planning on corporate organization and finance.

This engineering participation in management might be even more marked if it were not for the current shortage of engineers which puts a premium on their concentration on technical work. Serious as this shortage is, it should not be allowed to obscure the practical possibility that engineering and the industries served may advance farther and faster in the long run when engineering and management are thoroughly integrated.

The engineer with a well-informed interest in management, associated with a management which fully appreciates the potentialities of engineering, looks like a winning combination.

*How to Improve Engineering-Management Communications, Executive Research Survey No. 1, National Society of Professional Engineers (1121 - 15th St., N.W., Washington 5, D.C.).

Forty-Hour Farming

RECENTLY a farm paper ventured some predictions on the future of farm mechanization and electrification. It pictured 40-hour-week farming in 1977 with turbine-powered tractor units with enclosed air-conditioned cabs, automatic transmissions, hydraulic steering and power take-off, automatic levelling and safety stop features; once-over soil preparation, fertilizing, weed killing, and planting combines; and barnyard chore work largely handled by electric motors with time-switch controls.

This is no "Sunday supplement" sensationalism. The publication concerned is alert to its responsibility to agriculture, and its need of maintaining its prestige among practical farmers. Its predictions deal with recognized engineering possibilities along lines already marked by some definite progress.

Realization of these hopes for the future will depend largely on their economic justification. Can engineering development and refinement improve product performance, create a strong potential demand, and make that demand effective through quantity-production economy?

As in the past, farm mechanization will continue to advance with numerous, related short steps of agricultural-engineering progress. There is a challenge to agricultural engineers in the fact that farm leaders have learned to expect this progress and have stopped fighting against it. They are looking forward to the means by which they might farm on a 40-hour-week basis.

The New Era of Technology

IN CELEBRATING the Centennial of Engineering this year, the engineering profession will make its strongest effort to date to clarify its reason for being, the nature and extent of its service to humanity. It will attempt to interpret to its public the meaning of "Human well-being through engineered progress."

The human race in various times and places has lived through periods when its progress has been limited by its forms of government, customs, traditions, superstitions, low effectiveness of labor, shortage of capital, mismanagement, and slowness to accept the changes of technology. Now, in the United States and some other places, it appears to have entered into an era in which its progress may be limited primarily by its technical capacity.

Increased realization that we have entered this era can produce a public-opinion environment favorable to continued effective work by engineers.

It can help materially in recruiting the interest and best efforts of that part of the younger generation with strong aptitude for effective technical work.

It can help engineers to see their growing responsibilities in a new light.

A report to you about men and machines that help maintain International Harvester leadership

Precision-Mated Pistons and Sleeves

give McCormick® Farmalls® more endurance and pull power

Piston weight can't vary a tenth of an ounce from IH standards. This contributes to a smooth-running engine and steady pull power at all speeds. IH inspectors also use electronic gauges, graduated in millionths of an inch, to precision-mate IH pistons and sleeves. This helps to squeeze maximum power from each drop of fuel . . . lengthens Farmall engine life.

Pistons are color-keyed—red, white, and blue—according to the size of their wrist pin bore. Actually, there is only one ten-thousandth of an inch difference between each color. Wrist pins and connecting rods are similarly color coded. Assembling pistons, wrist pins, and connecting rods of the same color assures precision fit for long wear and quiet operation.

Check, check, and double-check. Experienced inspectors give each cylinder sleeve the "third degree." They make sure each sleeve is round, blemish free, and without taper. Then they use an electronic gauge to measure these precision-made sleeves. This measurement enables the inspectors to group and classify sleeves on the basis of minute differences in diameter.

Perfect mates for top performance. Here pistons and sleeves, previously sized and sorted, are precision-mated in a Farmall engine. There is less than five ten-thousandths of an inch difference between each of five piston and sleeve classifications. This assures the precision fit you'd expect in a fine watch. The workman is double-checking piston clearance with a ribbon and scale gauge.

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International Harvester products pay for themselves in use—McCormick Farm Equipment and Farmall Tractors . . . Motor Trucks . . . Crawler Tractors and Power Units . . . Refrigerators and Freezers—General Office, Chicago 1, Illinois.

AGRICULTURAL ENGINEERING

VOL. 33 MAY, 1952 NO. 5

Labor Requirements for Sprinkler Irrigation of Corn

By M. W. Bittinger and R. K. Frevert

ASSOC. MEMBER ASAE MEMBER ASAE

IRRIGATION of high-value crops in humid areas of the United States has been carried on in some localities for many years. However, in recent years considerable interest has developed in the irrigation of pastures, alfalfa, corn, and other field crops. A number of farmers in Iowa have recently purchased irrigation equipment to use primarily on corn. Many others are considering such action and have asked the Iowa Agricultural Experiment Station for advice. Obviously, in order best to advise these farmers, the benefits, problems, and costs of irrigation should be known. In Iowa, as in many other midwestern states, experimental work is under way to help determine the yield increases that may be expected due to irrigation. Such benefits must be determined over a period of several years, both dry and wet, in order to arrive at definite conclusions. Some of the problems and costs of irrigation, however, may be evaluated in a shorter time.

One of these problems, that of the labor requirement involved in the irrigation of corn, was considered to be important because

1 Corn production in this area is quite well mechanized, whereas portable sprinkler irrigation involves hand labor in moving pipe.

2 Corn often needs to be irrigated at a time when other work on a general grain and livestock farm is pressing. Such operations as haying and small grain harvest often compete with irrigation for available labor.

3 Although the portable pipes are light and easily coupled to one another, the operation of moving laterals is made difficult by tall corn. In general, the greatest need for irrigation is when the corn is at or near maximum height.

4 Working conditions are often disagreeable. It is generally still, hot, and humid in a cornfield during July or August; moreover, conditions are even more disagreeable after an irrigation when the foliage may be wet and the ground muddy. In most areas temporary labor for this type of work is difficult to obtain.

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1951, as a contribution of the Soil and Water Division. Approved for publication as Journal Paper No. J-2081 of the Iowa Agricultural Experiment Station. Project No. 1064.

The authors: M. W. BITTINGER and R. K. FREVERT, respectively, instructor and professor of agricultural engineering, Iowa State College, Ames.

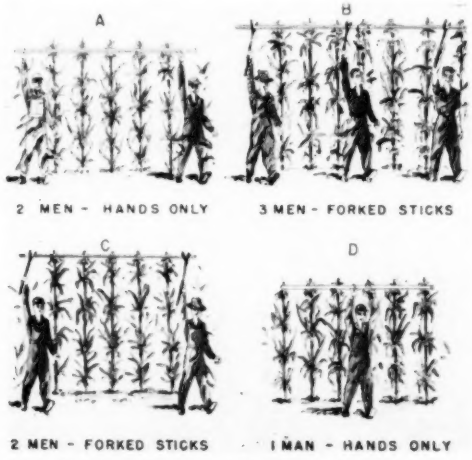

Fig. 1 This sketch illustrates methods of moving irrigation pipe in tall corn used by the authors in the field trials reported in this paper.

TEST PROCEDURE AND CONDITIONS

During the 1950 and 1951 seasons pipe-moving time trials were conducted in tall corn. These were carried out with 20-ft lengths of 5-, 4-, and 3-in aluminum pipe with quick-connecting couplers. Lengths of each size, both with and without sprinklers mounted on 5-ft aluminum risers, were used. In order to stabilize the 3- and 4-in sections that had risers, wooden cross members were fastened to the couplers.

The pipe was carried in both drilled and checked corn of various heights, through distances of 60, 80, and 100 ft. The time required to uncouple, carry, and reassemble the pipe, as well as the time required to walk back to the next section was recorded for each run. The pipe was carried by one, two, or three men both with and without forked carrying sticks. Fig. 1 illustrates these methods.

As no pumping was actually done during the time trials, there was no water remaining in the pipes. Also the ground and foliage were dry. It is, therefore, realized that the results represent minimum labor requirements.

RESULTS OF TIME STUDIES

Four operations (uncoupling, carrying, reassembling, and returning) were timed for the three pipe sizes and the three distances through which the pipe was moved. Table 1 is typical of the data obtained in these tests. The averages given in the table were obtained when two men carried one piece of pipe over the corn with their hands only, as shown in Fig. 1(a).

TABLE 1. Typical Data Obtained in Pipe Moving Tests

Crop: Checked corn 7 to 8 ft tall. Method: Two men using hands only

Operation		5-in		4-in		3-in	
		riser section, sec	blank section, sec	riser section, sec	blank section, sec	riser section, sec	blank section, sec
Average time required to uncouple length of pipe and lift into carrying position		2.7	3.3	2.8	3.0	2.8	3.0
Average time required to carry pipe designated distances	100 ft	22.5	20.5	22.5		25.0	24.0
	80 ft	17.0	15.0	19.5	19.0	20.5	19.5
	60 ft	14.8	13.8	15.5	15.5	14.0	15.5
Average time required to couple pipe		4.5	5.9	4.5	5.5	4.5	5.7
Average time required to walk back to next piece of pipe	100 ft			28.4			
	80 ft			25.4			
	60 ft			19.8			
Average total time required for complete cycle	100 ft	57.9	56.1	58.0		58.7	59.1
	80 ft	49.4	47.6	52.0	50.9	53.2	51.6
	60 ft	41.6	40.8	40.4	41.8	41.1	40.0

In this case there was little difference in the time required to move 3-, 4-, or 5-in pipe. In fact, in preliminary trials not reported here, more time was required to move the smaller sizes before cross members were attached to the couplers.

Slightly more time was usually required to lay the pipe down and couple it than to uncouple and lift it into carrying position, as indicated in Table 1. For this method it took very little more time on the average to perform the coupling and uncoupling operations with a piece of pipe having a riser and sprinkler than with a blank section. The time for coupling and uncoupling generally ranged from 2 to 5 sec; however, extremes of 10 to 15 sec occurred occasionally when lodged corn or weeds interfered with the operation.

TABLE 2. Minimum Labor Requirements for Moving 3- and 4-in Irrigation Pipe in Corn (60-ft moves)

Method used	Number of men	Corn height, ft	Checked or drilled	Man-hours per acre
(1) forked carrying sticks	2	8.0	drilled (pipe perpendicular to rows)	1.38
(2) forked carrying sticks	2	8.0	drilled (pipe parallel to rows)	1.16
(3) forked carrying sticks	2	7.8	checked	0.95
(4) hands only	2	7.8	checked	0.82
(5) forked carrying sticks	3	7.8	checked	0.81
(6) hands only	3	7.8	checked	0.55

LABOR REQUIREMENTS

Because this information is more usable in terms of labor requirements, the results of the time studies were converted into man-hours per acre. Table 2 summarizes these labor requirements. The data are tabulated for moving 3- and 4-in pipe through a distance of 60 ft in both checked and drilled corn. The calculations were made on the assumption that every other piece of pipe had a sprinkler and riser on it, although in most instances this made little difference.

Moving pipe through drilled corn required the greatest amount of labor. When the pipe was laid perpendicular to the drilled corn rows, difficulty was encountered in lowering and coupling it. Also under these conditions, there was no guide to aid in laying the lateral parallel to the previous setup. Coupling was easier but walking more difficult when the pipe was laid between the rows of drilled corn. The total labor requirement per acre was somewhat less with the pipe parallel to the rows (1.16 man-hours) than with the pipe perpendicular to the corn rows (1.38 man-hours). The height of the drilled corn necessitated the use of forked carrying sticks.

In checked corn it was possible to obtain data with and without the carrying sticks. As shown in Table 2, about 0.13 more man-hours per acre were required when the forked carrying sticks were used. The additional time was required in hooking the carrying sticks onto the pipe and later in getting the pipe laid on the ground. This was especially true if leaning corn caused interference when the pipe was being lowered.

When three men moved two sections of the pipe at once (method 5, Table 2), about the same total labor in man-hours per acre was required as when two men moved only one piece of pipe at a time with their hands. With the three-man method difficulty was occasionally encountered when the two pieces of pipe came apart just as they were being laid down.

The lowest labor requirement (0.55 man-hours per acre) was obtained when one man carried the pipe by hand. It is considerably more tiring for a man to work alone than with another person. Not only does the weight of the pipe become more important, but the 20-ft length of pipe held over one's head is somewhat unwieldy. This operation is especially difficult with larger pipe or with those having risers. There is also a possibility that the sprinkler head will become rammed into the ground and plugged as the worker attempts to lay the pipe down, and that some mud may be scooped into the end of the pipe as it is coupled.

INFLUENCE OF DESIGN ON LABOR REQUIREMENTS

Table 2 gives only the labor requirement for moving the portable sprinkler lines. When considering the total labor requirement, allowance must be made for such factors as the time required to walk to and from the lateral, to prime the pump, to allow the pressure to build up, and to service the power unit. The amount of time spent in most of these operations is directly dependent upon the number of lateral moves required to cover a certain acreage. In order to determine how the design of a system may influence the total labor requirements, three irrigation designs were prepared for a 40-acre field. The designs differed only in the spacing and the size of the sprinklers. In each case a water supply of 300 gpm was assumed at the center of the 40-acre field. The three spacings were 40 x 60 ft and 60 x 80 ft with small sprinklers, as well as a 220-ft square spacing with one large sprinkler. Table 3 shows that the labor requirement is reduced from 1.47 to 1.10 man-hours per acre as the sprinkler size and the spacing are increased. This reduction may conceivably compensate for the additional power and fixed costs required by larger systems.

The values given in Table 3 for total labor requirement become more significant when one considers that the total labor requirement for preparing a seed bed, planting, cultivating and harvesting an acre of corn may be as low as four man-hours per acre. Three irrigations per season by the 40 x 60-ft system of Table 3 could more than double the labor required for raising an acre of corn.

TABLE 3. Minimum Total* Labor Requirements per Irrigation Using Method No. 5 in Table 2

Sprinkler spacing	No. of sprinklers	No. of lateral moves	No. of main line moves	Labor requirement per irrigation (man-hours per acre)
40 x 60 ft	16	44	2	1.47
60 x 80 ft	11	32	2	1.25
220 x 220 ft	1	86	2	1.10

*Includes time spent walking to and from lateral, priming pump, and moving main line, but does not include allowance for lost time caused by breakdowns, plugged sprinklers, etc.

CONCLUSIONS

It should be recognized that the results given here should be used only as a general indication of the labor requirements for irrigating corn with portable sprinkler equipment and also that the values may vary considerably under different human, crop, and soil conditions. With these qualifications, the following conclusions are derived from the original data:

1. Pipe size makes little difference in total time required when more than one man handles the pipe.

2. Slightly more time is required to uncouple a blank piece of pipe than a length of pipe having a riser, but the opposite is true for coupling the pipe.

3. More time is required to move pipe in drilled corn than in checked corn, especially when the pipe is laid perpendicular to the drilled corn rows.

4. Slightly more time is required to move pipe with forked carrying sticks than with hands only.

5. The time required to couple and uncouple the pipe may occasionally be increased by as much as four to five times because of such variables as lodged corn, weeds, and instability of riser sections.

6. The labor required for moving laterals in tall corn is usually between 0.8 and 1.0 man-hour per acre, but it may vary outside these limits for different conditions and methods of moving the pipe.

7. The total labor required depends also upon the design of the system in that as sprinkler size and spacing are increased fewer moves are necessary. In the case studied the total labor was reduced from 1.5 to 1.1 man-hours by increasing the spacing from 40 x 60 ft to 220 x 220 ft.

8. With three irrigations per season, the minimum total labor requirement for irrigating corn may exceed the minimum total labor required for all other corn-production operations.

Hydraulic Capacity Requirements for Control of Farm Implements

By Wayne H. Worthington and J. Waldo Seiple
MEMBER ASAE

THE purpose of the recently adopted ASAE-SAE Standard: "Application of Hydraulic Remote Control to Farm Tractors and Trailing Type Farm Implements," is to make possible the interchangeable use of any make or model of trailing-type farm implement, adapted to hydraulic remote control, with the hydraulic system (including a remote cylinder) of any make or model of farm tractor developing maximum drawbar pull consistent with the normal operation of the implement.

Physical interchangeability of tractors and implements along the desired lines results from the application of three conditions now included in the present standard, as follows:

1 That all hydraulic cylinders with working strokes of 8 in and 16 in have common mounting, operating, and outline dimensions, respectively.

2 That all drawn implements intended for use with such respective cylinders have common mounting, operating, and clearance dimensions.

3 That the length of the connecting hoses included with the tractor and the position of the cylinder on the implement be such as to reduce the necessity for supplemental hose lengths or piping and to permit full maneuverability when turning and operating over irregular ground.

The fullest measure of functional interchangeability will be obtained only by proper matching of tractor drawbar power and hydraulic capacity with implement draft and the hydraulic effort necessary for control and lifting.

Some six years have elapsed since this program of standardization was initiated. During this time, a coordinated effort

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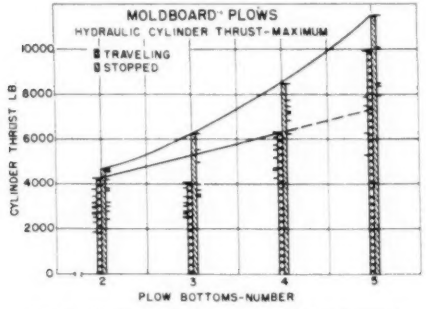

Fig. 1 MOLDBOARD PLOWS (12, 14, and 16-in bottoms)

Number of bottoms	Max. cyl. thrust, lb Traveling	Stopped	Number of bottoms	Max. cyl. thrust, lb Traveling	Stopped
2	4275	4700	4	6300	8500
3	4050	6250	5	9950	11500

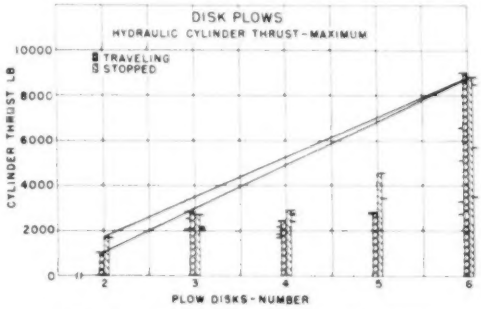

Fig. 2 DISK PLOWS (24, 26 and 28-inch disk diameters)

Number of disks	Max. cyl. thrust, lb Traveling	Stopped	Number of disks	Max. cyl. thrust, lb Traveling	Stopped
2	1030	1770	5	2800	4575
3	2880	2750	6	9050	8850
4	2450	2900			

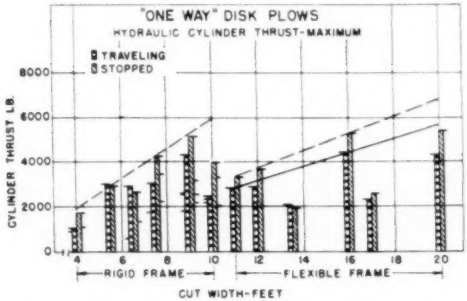

Fig. 3 "ONE WAY" PLOWS (Variously designated as disk tillers, harrow, and Wheatland plows)

Rigid frame	Max. cyl. thrust, lb Traveling	Stopped	Flexible frame	Max. cyl. thrust, lb Traveling	Stopped
4 ft	1075	1750	11 ft	2875	3325
5½ ft	3010	2950	12 ft	2910	3680
6½ ft	2960	2660	13½ ft	2125	1960
7½ ft	3050	4280	16 ft	4460	5300
9 ft	4350	5170	17 ft	2365	2600
10 ft	2500	4000	20 ft	4360	5420

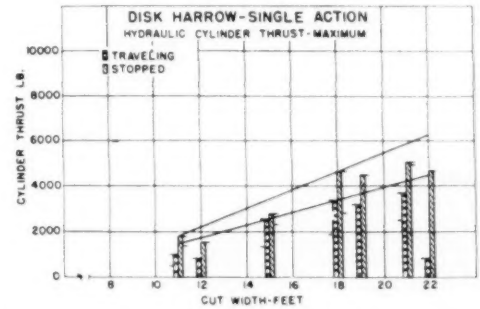

Fig. 4 DISK HARROW, single action

Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped	Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped
11	1000	1825	19	3200	4500
12	850	1550	21	3700	5050
15	2550	2800	22	850	4675
18	3390	4660			

on the part of tractor and implement manufacturers, operating under widely varying field conditions, has produced a mass of information regarding the lifting and control characteristics of implements. New types of field test equipment have been designed and built, new test procedures have been developed, and the results of hundreds of field tests have been pooled for analysis and comparison.

In many cases, where the results appeared out of line, implement lifting linkages have been modified and tests repeated. To the tractor engineer has fallen the task of providing a hydraulic system, including a cylinder, with sufficient working capacity to lift and control the largest implement consistent with the drawbar power of the tractor; to the implement engineer has fallen the job of holding to a minimum the cylinder thrust necessary to lift or control the implement. The common attainment of these objectives by the implement and tractor factories of any one manufacturer has been a matter of common education requiring the greatest skill and closest cooperation of all engineers concerned. As the objectives expanded to include the entire industry, the task ahead was prodigious, although now within sight of realization.

Data in regard to implements operated with wheel-type tractors is sufficiently complete to permit comparative analysis. Some little information is available regarding the performance of implements outside of the drawbar capacity of wheel tractors, but it is not conclusive and was not included in the preparation of this study. This paper is, therefore, limited to a summary of the performance of wheel tractors and implements within their drawbar capacity, using hydraulic cylinders with 8-in working stroke. (No data from tests with cylinders with 16-in stroke are included in this report.)

Definite characteristics, trends, and limitations are evident. Although not conclusive, the results indicate the possibility of arriving at a further "standard", which will affect the desired functional interchangeability.

Origin of Data. The values of hydraulic cylinder thrust necessary to lift or otherwise control the operation of various sizes and types of implements have been determined under conditions chosen by the respective implement manufacturers as representative of normally severe operating conditions — those under which satisfactory performance may be reasonably expected. Tests considered as not representative, due to abnormal conditions, were eliminated.

In order that all data may be considered on a common basis, the drawbar power of each implement is taken as that of the smallest tractor designated by the implement manufacturer as suitable for its operation under most favorable conditions. The drawbar performance of all tractors is that established officially at Nebraska. The horsepower and drawbar pull values recorded are those of test G, operating in the same gear ratio as that chosen by the manufacturer for ten-hour test H. This reflects each tractor manufacturer's choice as to the most

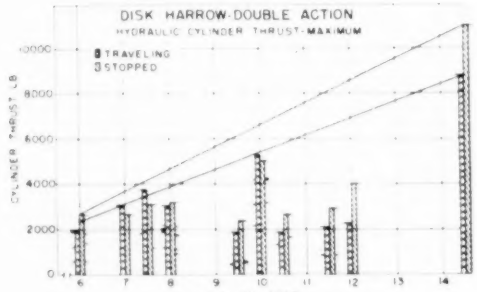

Fig. 5. Disk Harrow, double action.

Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped	Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped
6	1960	2680	10	5280	5000
7	3000	2670	10½	1900	2650
7½	3740	3070	11½	2100	2950
8	3080	3210	12	2250	4001
9½	1900	2400	14½	8080	11610

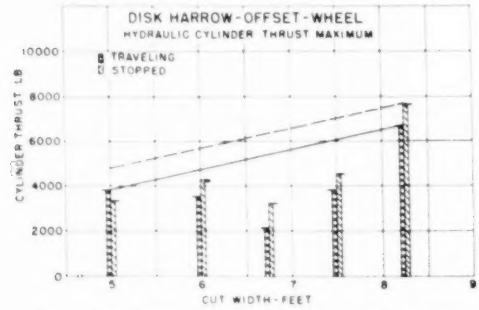

Fig. 7. Disk Harrow, Offset (wheel type) (22 and 24 in disk diameter).

Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped	Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped
5	3820	3350	7½	5850	4320
6	3540	4500	8½	6700	7650
6½	2120	3350			

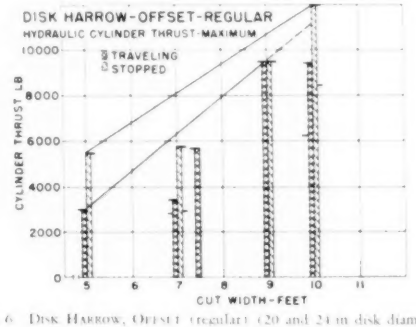

Fig. 6. Disk Harrow, Offset (regular) (20 and 24 in disk diameter).

Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped	Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped
5	3020	5490	9	9500	9500
7	4460	5780	10	9450	11970
7½	5700	——			

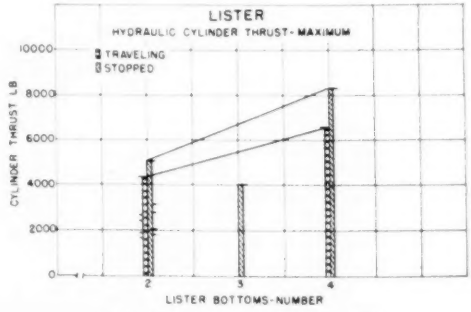

Fig. 8. Listers (including filled seed cans).

Number 14-in bottoms	Max. cyl. thrust, lb Traveling	Stopped
2	4350	5050
3	——	4030
4	6590	8300

efficient operating speed for his particular tractor. This is the performance of spark-ignition engines with operating maximum carburetor adjustment and of diesel engines with the maximum fuel-pump delivery permitted by the governor.

Tractor "plow ratings" (rating as to number and sizes of plows pulled by each tractor) are, with two exceptions, those published in *Implement and Tractor* vol. 66, no. 22, October 27, 1951, and compiled from data supplied by the tractor manufacturers. In these two exceptions, each of the manufacturers gave their approval of the rating finally used.

Presentation of Data. Maximum cylinder thrust values for the lifting and control of various groups of implements are presented in both tabular and chart form (Figs. 1 to 8). The disproportionate increase in the cylinder thrust necessary to raise the 5-bottom plow (Fig. 1) reflects the heavy duty imposed by implements built with sufficient strength for operation with track-type tractors. The severe lifting requirement of the heavy-duty-type implements is also shown in Fig. 2.

The cylinder-thrust capacity necessary to lift a number of miscellaneous implements for which no bar charts have been prepared is as follows:

LANDLEVELERS

Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped
6	4720	4720
8	6580	5770
10	6880	7240

FIELD CULTIVATORS

Width of cut, ft	Max. cyl. thrust, lb Traveling	Stopped
8	1550	3280
12	1675	2690
14½	1890	4570

COMBINATION (UNIT) CARRIER

Tools	Max. cyl. thrust, lb Traveling	Stopped
Border disk—two gang (20, 22, and 24 in disk diameter)	4410	6790
Chisel cultivator		
One chisel, 14 in deep	—	7600
Three chisels, 21 in deep	4420	9660
Five stiff teeth, 8 in deep	8600	8600
Thirteen stiff teeth, 8 in deep	9800	—
5-ft with six standards and shovels	—	4540
7-ft with three standards and chisel points 12½ in deep	7850	10670
7-ft with 15 spring teeth 14 in deep	5400	8500

LANDSHAPER

5-ft with two 24-in extensions	1360	1090
6-ft with two 36-in extensions	710	750

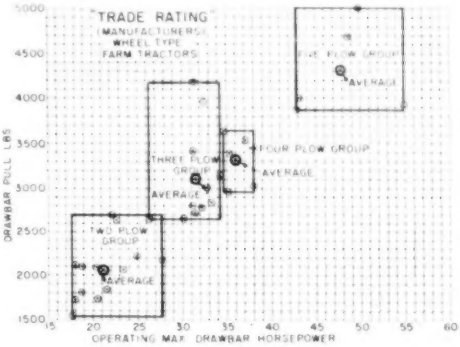

Fig. 9

GRAIN DRILLS (hopper filled)

Width, ft	Max. cyl. thrust, lb Traveling	Stopped	Width, ft	Max. cyl. thrust, lb Traveling	Stopped
7½	825	760	12	800	1050
9½	1970	2125	13½	1825	1975
10	—	1880	14	1650	1890

	POTATO PLANTER Max. cyl. thrust, lb Traveling	Stopped	POTATO DIGGER Max. cyl. thrust, lb Traveling	Stopped
Two-row	1120	1210	Single-row	1030	850
			Two-row	2890	2450
POWER MOWER			COMBINE		
7-ft semi-integral	500	500	5½-ft	—	2250
ENSILAGE HARVESTER			AUTOMATIC BALER		
Single-row	—	800		—	1050
WINDROWER			CORNPICKER		
16-ft	—	5120	Two-row	—	565

Throughout the trade, it is customary to refer to tractors with reference to the number of moldboard plow bottoms they are capable of pulling under "average" conditions. This "plow rating", for which no definition is officially established or accepted, is found in the advertising literature of all wheel tractor manufacturers. A comparison of these ratings with official Nebraska Test performance is given in Table 1 and shown graphically in Fig. 9.

The data in Table 1 may be further resolved into drawbar horsepower and drawbar pull per bottom as given in Table 2.

The wide difference in "plow rating" found between tractors of different manufacturers largely reflects differences in plowing speeds. The accepted measure of drawbar performance is drawbar horsepower, since it includes factors of both speed and draft. As might be expected, our analysis shows that the minimum values of drawbar horsepower per bottom form the most consistent index of power requirement throughout the full two to five-plow range.

Under favorable operating conditions, a given drawbar horsepower will operate a larger and heavier im-

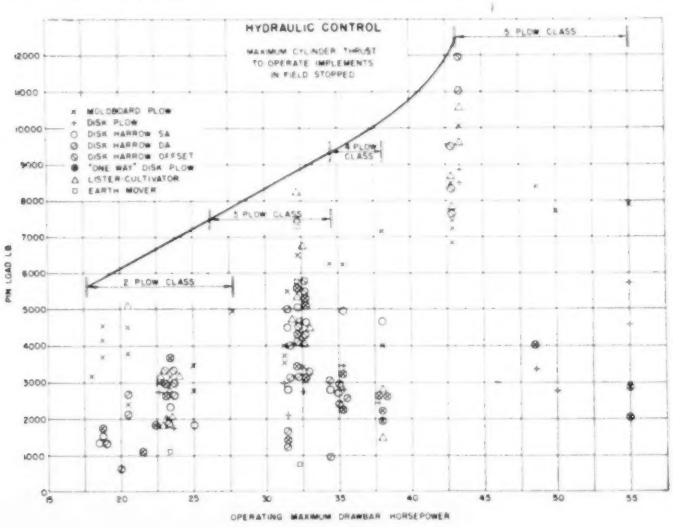

Fig. 10

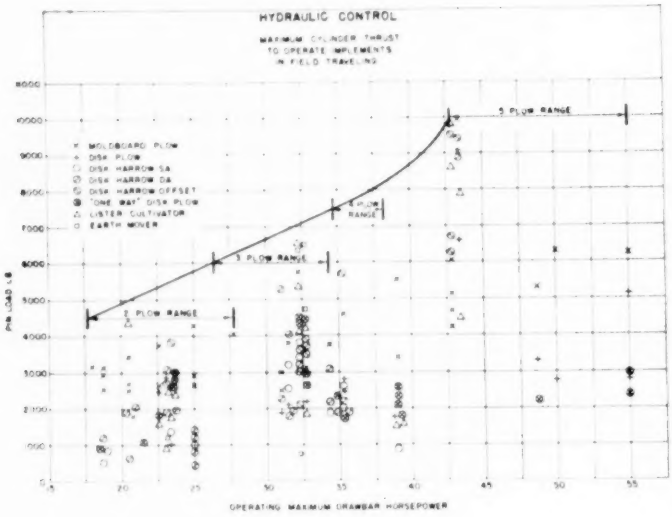

Fig. 11

TABLE 1. Drawbar Performance
(Tractor Manufacturers' Trade Rating)

	Maximum	Minimum	Average
2 plow rating			
Drawbar horsepower	27.76	17.69	21.12
Drawbar pull, lb	2693	1540	2055
3 plow rating			
Drawbar horsepower	34.58	26.34	31.56
Drawbar pull, lb	4175	2652	3103
4 plow rating			
Drawbar horsepower	58.07	34.58	36.09
Drawbar pull, lb	5632	2958	3508
5 plow rating			
Drawbar horsepower	54.01	42.86	47.89
Drawbar pull, lb	5054	3864	4503

plement than under unfavorable conditions. It follows that any matching of tractor drawbar performance with accompanying hydraulic cylinder lifting effort may properly be on the basis of minimum tractor power and maximum cylinder thrust for each implement-tractor group. In Fig. 10, the maximum values of cylinder thrust necessary to raise or control implements while traveling are plotted as ordinates against abscissas representing the drawbar horsepower of the smallest

TABLE 2. Drawbar Horsepower and Pull per Plow Bottom
(Tractor Manufacturers' Trade Rating)

	Maximum	Minimum	Average
2 plow rating			
Drawbar horsepower	13.88	8.85	10.56
Drawbar pull, lb	1347	770	1027
3 plow rating			
Drawbar horsepower	11.46	8.78	10.52
Drawbar pull, lb	1391	884	1034
4 plow rating			
Drawbar horsepower	14.52	8.65	9.02
Drawbar pull, lb	1408	765	827
5 plow rating			
Drawbar horsepower	10.98	8.57	9.58
Drawbar pull, lb	1007	773	861
Average			
Drawbar horsepower	11.46	8.71	9.92
Deviation, plus	23.1%	1.5%	6.5%
minus	16.8%	1.5%	9.1%
Drawbar pull, lb	1185	798	937
Deviation, plus	17.6%	10.8%	10.3%
minus	24.9%	4.4%	11.7%

tractor designated by the implement manufacturer as having sufficient power to pull the implement under favorable conditions. Also indicated are the tractor power ranges applicable to each of the implement-tractor groups shown in Fig. 9. The step diagram shows the minimum remote hydraulic cylinder thrust found necessary for the satisfactory operation of all implements in each implement-tractor group as follows:

2-plow group	4500 lb
3-plow group	6000 lb
4-plow group	7500 lb
5-plow group	10000 lb

The remote hydraulic cylinder thrust values necessary to raise or control these same implements while stopped, with tools in ground, have been similarly plotted on Fig. 11. Lifting implements from their full working position while stopped is generally considered an emergency requirement. For this reason, emergency advantage may be taken of the capacity of the hydraulic system beyond its rated value and below that at the relief-valve cracking pressure. Assuming that rated hydraulic thrust may be developed at 80 per cent of the relief valve opening pressure, the maximum permissible thrust values become 25 per cent greater than rated. Minimum hydraulic cylinder thrust values to lift or control the implements in each of the groups when stopped, and which should be exerted at pressures not exceeding relief valve opening pressure, were found to be as follows:

2-plow group	5625 lb	4-plow group	9375 lb
3-plow group	7500 lb	5-plow group	12500 lb

In Fig. 11, the step diagram shows that, with a single exception, all of the implements reported could be lifted with minimum cylinder thrust values shown. Since some manufacturers choose to establish the rating of their hydraulic system at less than 80 per cent of the relief valve opening pressure, it is suggested that a rating on the basis of 80 per cent of relief valve pressure is as high as may be found desirable.

As a basis of comparison, Fig. 12 shows the thrust of the 8-in stroke cylinders included as a part of the hydraulic systems of current wheel-type farm tractors. These values have been computed from published dimensional and pressure data supplied by the tractor manufacturers, considering average fluid frictional losses and mechanical efficiencies experimentally determined.

CONCLUSIONS

1. All of the wheel-type tractors studied were found to fall within well-defined groups on the (Continued on page 278)

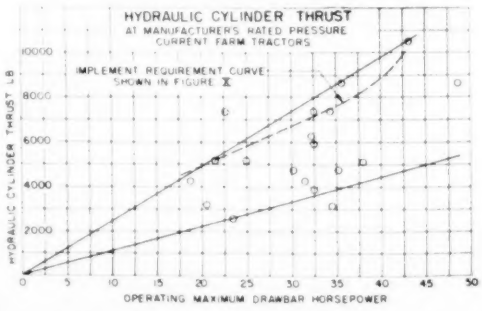
HYDRAULIC CYLINDER THRUST
AT MANUFACTURERS' RATED PRESSURE
CURRENT FARM TRACTORS
IMPLEMENT REQUIREMENT CURVE SHOWN IN FIGURE 9
HYDRAULIC CYLINDER THRUST LB
OPERATING MAXIMUM DRAWBAR HORSEPOWER

Fig. 12

Relating Basic Resources in Irrigation Research

By George D. Clyde
MEMBER ASAE

IRRIGATION agriculture may be divided into two major aspects: (a) agronomic and (b) water management. Optimum water management and agronomic practices require a consideration of the basic elements of soil, water and plants. In establishing water-management practices, soil and water are of major importance, while agronomic practices are governed largely by soil and plant requirements.

Agronomic Aspects. The agronomic aspects deal primarily with the soil as a plant food source, soil-air-moisture relations, fertilizers, salinity, tillage practices, crops, rotations and management and their effect on plant response and crop production.

Water-Management Aspects. The water-management aspects involve water and soil. Irrigation agriculture requires the artificial application of water to fill or replenish the soil-storage reservoir. The water supply and its physical control is of major importance in any irrigation development. Design of the irrigation distribution system is dependent upon the seasonal and maximum monthly irrigation water requirements of crops to be grown. The farmer's water-management practice should be guided by the net irrigation water requirements of the crop.

The most difficult problem in water management relates to the method of water application to be used. The objective of an irrigation is to distribute the water uniformly over the field so as to fill the soil-storage reservoir and have a minimum surface runoff, deep percolation, minimum erosion and a maximum efficiency in use of water and labor.

Soil pore space is the reservoir. An application of irrigation water should fill this reservoir. The water must enter the soil through the boundary layer which is usually the soil surface. After it gets into the soil, it must move through the interstices between the soil particles until the pore space is filled. The movement through the gate or the soil surface is called infiltration, and the movement through the successive layers of soil is called permeability.

Prior to the establishment of an irrigation or water-management practice, the soil to be irrigated should be characterized with respect to the movement of water into and through it. The principal factors to be evaluated are bulk density, wilting point, field capacity, infiltration rate, and permeability at the different soil horizons. After establishing for a given field the initial and final intake rate, the permeability and the storage capacity, the method of application most suitable to the crop, the topography, the water supply and the soil can be determined.

There are two principal methods of applying water: surface and sprinkler. In the first case, whether it be by furrow, border or basin, the infiltration rate or the permeability, whichever controls, will influence the size of stream, the length of run, the length of the border or the area of the basin. The slope will also influence the size of the stream and the length of run.

For each set of conditions there is an optimum length of run for a given size of stream, slope and permeability. If the size of the stream is fixed by the erodibility of the soil, the proper length of run can be determined. Good water management requires an evaluation of these factors for every different site condition, and the selection of a method of application which will be most efficient in water and labor and least costly in terms of soil erosion.

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Houston, Tex., June, 1951, as a contribution of the Soil and Water Division.

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Drainage of Irrigated Lands. It is neither possible nor desirable to apply to an irrigated soil only sufficient water to meet the plant requirements. A small amount of water must move downward to avoid the formation of limiting layers by deposition or to maintain a proper salt balance in the soil.

MOST IRRIGATION APPLICATIONS ARE EXCESSIVE

Most irrigation applications are excessive. These excess applications, together with seepage from canals and natural channels, cause some waterlogging or salt accumulation in most irrigated areas. Artificial drainage becomes necessary to correct this situation. Removal of excess water from the soil involves many of the same factors that are important when adding water to the soil. For example, before a drainage system can be designed the source and amount of water to be intercepted or removed must be determined. The soil profile must be characterized to establish the rate at which water will move through it. The final position and permissible fluctuation of the water table must be fixed and the leaching necessary to maintain a proper salt balance established. With these facts known, a drainage system can be designed to intercept or remove the excess water and/or salt.

It has been said that "an agriculture based upon irrigation cannot endure." This is a challenge to man. There are numerous examples of civilizations dependent upon irrigation agriculture that have endured since the beginning of time. There are others that have decayed because of the misuse of their soil and water resources.

Teamwork in Conservation. Irrigation agriculture can endure, but it will require wise use and the complete conservation of two of the basic resources, soil and water. It requires teamwork in research, education and action.

Research may be defined as finding facts and putting them to use. The objective in irrigation agriculture is: to isolate all the causal factors, evaluate them, combine them, and from them establish information and methods of use which will make possible a permanent and profitable agriculture.

Prior to World War II, scientific knowledge developed largely as a result of individual effort. The atomic bomb, aureomycin, rockets and supersonic aircraft required both pure and applied research and teamwork. These, along with many other developments during the past 10 years, have demonstrated that greater progress can be made by welding individual efforts into team effort. So it is in irrigation agriculture.

In the past, too frequently, the researchers have conducted independent research in soils, water, and plants. Little or no attempt was made to relate these basic resources. As a result, erroneous conclusions were often drawn or long delays resulted before the pieces could be welded together for a solution. Today the U.S. Department of Agriculture and the state agricultural experiment stations, in close cooperation, have developed the team approach to the problems of irrigation agriculture. It works like this: The problem originates on the land. It may be on presently irrigated land or on land proposed for irrigation. The problem is studied by (a) local groups, (b) action agencies (such as the U.S. Bureau of Reclamation and the operations division of the U.S. Soil Conservation Service), (c) educational agencies (agricultural extension services), (d) research agencies (state agricultural experiment stations, Soil Conservation Service-Research, and the U.S. Bureau of Plant Industry, Soils, and Agricultural Engineering). After the problem has been set forth and a plan of attack developed, a group of research technicians qualified in their respective fields is assigned to conduct the research work. The research includes both basic and applied studies, and as results are obtained, they are picked up by educational agencies for dissemination to the public, and by the action agencies for reduction to practice under site conditions involved.

THE TEAM APPROACH IN IRRIGATION RESEARCH

A typical example of the team approach is the cooperative research project under way at the Greenville Farm, Logan, Utah. This project involves a joint study of the water, soil, and plant aspects of irrigation agriculture. The title of the project is "Irrigation, Fertilization and Soil Management of Alfalfa and Associated Crops in Rotation." The project is being conducted cooperatively by the Utah Agricultural Experiment Station, the Soil Conservation Service (Research), and the Bureau of Plant Industry, Soils and Agricultural Engineering, together with several commercial companies. The three basic phases (water, soil, plants) are each under the direct supervision of a project leader trained in that phase. The three leaders working together integrate the entire project into one well planned and coordinated effort. The major objectives of this project are:

1. To determine the interrelations among the several factors of crop production (fertilization, time, method and amount of irrigation) in relation to the yield and quality of the several crops in the rotation.

2. To evaluate the immediate and residual effects of various fertilizer and irrigation treatments on crop quality and yield.

3. To determine the most effective and efficient use of irrigation water and fertilizer for crop production in rotation.

4. To study the relationships among soil moisture, soil aeration and crop production.

5. To determine the effect of various cultural practices upon soil permeability and water infiltration.

6. To study irrigation efficiencies, methods of water application and control.

The project includes five crops in a common rotation replicated four times. Each crop is irrigated by two methods, furrow and sprinkling, with four levels of irrigation under each method. The irrigation plots are 45 x 50 ft and within each irrigation plot there are eight fertilizer plots, making a total of 1,280 separate plots in the experiment.

The preparation of the ground, the planting, the fertilization and harvesting of the crop is under the direct supervision of Dr. J. L. Haddock, agronomist, Bureau of Plant Industry, Soils, and Agricultural Engineering. The soils aspect, which includes the soil moisture determinations and a characterization of the soils, is under the direction of Dr. Sterling S. Taylor, soil physicist, Utah Agricultural Experiment Station. The irrigation aspects are under the direction of Dr. Vaughn E. Hansen, irrigation engineer, Soil Conservation Service.

The project, now entering the third year of a 5-year rotation, illustrates graphically the interdependency of the three phases. All data from the three phases are entered on IBM cards, using the mark sensing system. On these cards are recorded both the soil moisture and irrigation data. Each day the cards are turned in to the IBM laboratory and the data are summarized and analyzed and made available for use the following morning. Based on this data, the plots needing irrigation are determined and the amount of water needed to bring the root zone up to field capacity calculated. This information is passed on to the irrigator and he makes the water application for the day. He records the amount, rate and time of application on the card for analysis later the same day. These current reports on application serve as checks on moisture determinations and greatly increase the efficiency of the project. The current data on moisture and water applications are related to the growth and condition of the crops.

Some other areas where cooperative work between SCS, BPISAE and state agricultural experiment stations is under way are: Redfield, S. D.; Ontario, Ore.; Grand Junction, Colo.; Gunnison, Colo., and Laramie, Wyo.

What is purported to be the world's largest "garden hose" and a new spray rig designed by engineers of the Hawaiian Pineapple Co. are shown in action in this picture, in irrigating pineapple plantations at Lanai, Hawaii. The portable sprayer delivers water to the pineapple plants at the rate of 700 gpm. In an 8-hr day it can irrigate 12 acres with the equivalent of 1.5 in of rainfall. The hose was developed by United States Rubber Company to withstand a pressure of 125 psi. It is 4 in. in diameter and 800 ft in length. The mammoth hose reel and spray booms are mounted on a truck which moves slowly down the rows as hose unrolls behind it.

SUMMARY

Irrigation is a means to an end. Water, soil and plants are the basic resources. To completely develop and utilize these resources on a permanent and profitable basis requires the joint efforts of the research, educational and action agencies. Joint planning, teamwork in research and full support of the action agencies will guarantee full and efficient use of the presently developed resources and the ultimate full development and efficient use of the new undeveloped resources of the West.

Hydraulic Capacity Requirements for Control of Farm Implements

(Continued from page 276)

basis of "plow ratings"; i.e., number of moldboards which may be pulled under average severe working conditions.

2. The minimum tractor drawbar power required per bottom shows a close correlation throughout the entire 2 to 5-plow range.

3. The ever-existing tendency toward more available power at the drawbar is being reflected in the newer tractors as higher working speeds, with an increasing power-to-weight ratio. In a given "rating" group, this may be expected to influence the maximum tractor power per bottom more than the minimum.

4. The maximum hydraulic cylinder thrust necessary for lifting or controlling the various implements of each group (considered as plow bottom draft equivalents) patterns with the minimum tractor drawbar power required to operate the same implements under favorable conditions. This is true whether traveling or stopped.

This information and data are presented in the hope that an acceptable standard may be developed, relating the drawbar performance of any tractor with the thrust of the remote cylinder included as a part of its hydraulic system. It would appear that the greatest usefulness of such a standard will result only as it becomes possible to define the maximum permissible cylinder thrust allowable for the lifting or control of any implement with respect to a known power requirement.

ACKNOWLEDGMENT: The authors desire to acknowledge the time and effort so generously given by the following participating manufacturers and their engineers in the activities leading to the development of the ASAE-SAE Standard: "Application of Hydraulic Remote Control to Farm Tractors and Trailing-Type Farm Implements": Allis-Chalmers Mfg. Co., J. I. Case Co., Caterpillar Tractor Co., Deere & Co., International Harvester Co., Massey-Harris Co., Minneapolis-Moline Co., and The Oliver Corp. Special appreciation is expressed for the efforts of E. W. Tanquary, whose leadership and perseverance led to the accomplishment of the objectives of the standardization effort.

Numerical Analysis of Flow Through Aquifers Toward Wells

By James N. Luthin and V. H. Scott
ASSOCIATE MEMBER ASAE

THE flow of water toward wells has long been a subject of extensive investigation from both a theoretical as well as a practical point of view. Many flow theories have been developed using certain approximations. In general, the assumption is made that the flow at any point is proportional to the slope of the water table at that point. This assumption (called the Dupuit-Forchheimer assumption) results in equations which give approximate values for the flow into the wells, but give inaccurate pictures of the flow conditions in the aquifers which conduct the water. Muskat (4)* has discussed the limitations of the Dupuit-Forchheimer assumption at some length and it will not be necessary to elaborate on his discussion.

While a computation of the flow as given by the Dupuit-Forchheimer condition is certainly desirable, it is essential for an understanding of the problem to have a clear physical picture of the flow pattern, i.e., the paths of flow or flow lines and the distribution of hydraulic head around the well. In this paper a numerical method of obtaining this physical picture is presented and used to examine four cases typical of field conditions.

In 1897 Slichter (6) pointed out that the flow of fluid through porous media satisfied Laplace's equation. He also pointed out that solutions of Laplace's equation in cylindrical coordinates,

$$\frac{\partial^2 \phi}{\partial r^2} + \frac{1}{r}\frac{\partial \phi}{\partial r} + \frac{\partial^2 \phi}{\partial z^2} = 0 \qquad [1]$$

where ϕ = hydraulic head, i.e., the height above a reference plane to which water will rise in a pipe or piezometer, r = radial distance from the z axis, z = vertical distance along z axis, would give the flow lines and isopiestic lines (lines of equal hydraulic head) for a specified well problem. The angle coordinate is omitted because of cylindrical symmetry.

Solutions of Laplace's equation are available for problems having simple geometric dimensions with uniform permeability but are very difficult to obtain for problems of complicated geometry or where changes of permeability occur. For the more complicated problems it is necessary to resort to other means of solving Laplace's equation. The authors used the method of numerical mathematical analysis†.

Numerical analysis possesses the advantage of relative simplicity; no special mathematical training is required to solve a problem when it has once been outlined. It possesses the disadvantage of being tedious and time-consuming. Machine techniques such as IBM punch cards can be used but are costly and not generally available to workers in the field.

The approximate solution of differential equations by numerical methods is as old as Newton, but it is only in recent years that several new variations of the old methods have increased the speed and scope of their application. Basically all of the methods are similar. The region under consideration is covered with a grid or network of points. Known values of hydraulic head are placed on boundary points, and arbitrary initial values of hydraulic head are assigned to interior points. Improvement formulas are then used to get better values at the interior points. The procedure is repeated until further application of the improvement formula results in no further change of the values at the network points. The problem is then considered solved for the particular net spacing used. Reduction of the net-spacing interval results in greater accuracy at the expense of large increase in the amount of labor required.

METHODS OF ANALYSIS

1 *Drawing the Net.* A scale drawing is first made of the region under consideration. All important features are indicated such as the well, impermeable layers, the aquifer, the surface of the water table, and layers of various permeability. The region is then subdivided into uniform squares of large size. A coarse net is used at first for speed and is later subdivided for greater accuracy.

2 *Boundary Condition.* If the distribution of hydraulic head is desired as a solution of the problem‡, values of hydraulic head or of its first derivative must be assigned to grid points lying on the boundary of the region. In the study of an idealized field problem, it is customary to make certain convenient assumptions. One is that the hydraulic head over the perforated section of the well casing is uniform and equal to zero. The surface of a flat water table is regarded as a piezometric surface on which the hydraulic head is constant and is assigned an arbitrary value of 1,000 or multiples thereof. Where the water table is sloping, the hydraulic head at any point on its surface is taken to be equal to the vertical distance of the point from the reference plane. In the case of an artesian aquifer which is confined between impermeable layers, it is necessary to limit the radial extent of the problem. An arbitrary vertical isopiestic line is drawn in at a distance sufficient from the well for the flow to be truly cylindrical. In most cases a distance equal to twice the thickness of the aquifer is sufficient to insure a cylindrical distribution of hydraulic head.

No flow occurs across impermeable layers or the center line of the well. The normal derivative of the hydraulic head along these lines is equal to zero.

3 *Basic Improvement Formula.* Improved values at interior points are calculated by use of the basic improvement formula which is obtained in the following manner. Consider a small portion of a network of points as in Fig. 1. Arbitrary values of hydraulic head are assigned to the various points of the net. For convenience we will just consider points a, b, c, d, and e which have initial values of hydraulic head of ϕ_a, ϕ_b, ϕ_c, ϕ_d and ϕ_e. A more accurate value of the hydraulic head is wanted at point e. This more accurate value will be determined from the hydraulic head at the four nearest adjacent points, a, b, c, and d. Essentially we solve Laplace's equation approximately. Approximate values are first determined for the derivatives in r direction. At point P_2 lying halfway between points e and b, the first derivative is approximately

$$\left.\frac{\partial \phi}{\partial r}\right]_{P_2} \approx \frac{\phi_2 - \phi_3}{h}$$

At point P_4 lying halfway between points e and d, the first derivative is approximately

$$\left.\frac{\partial \phi}{\partial r}\right]_{P_4} \approx \frac{\phi_0 - \phi_4}{h}$$

This paper was presented at a meeting of the Pacific Coast Section of the American Society of Agricultural Engineers at Los Angeles, Calif., February, 1951.

The authors: JAMES N. LUTHIN and V. H. SCOTT, each assistant professor of irrigation, University of California, Davis.

*Numbers in parentheses refer to the appended references.

†Other important methods such as the electrical analogue are omitted from this discussion.

‡The distribution of hydrostatic head or velocity of flow or lines of flow can also be determined since they are all potential functions satisfying Laplace's equation. The boundary conditions must be modified to give the desired result.

At point e the first derivative is approximately

$$\left.\frac{\partial \phi}{\partial r}\right]_e \approx \frac{\phi_2 - \phi_4}{2h}$$

so

$$\left.\frac{1}{r}\frac{\partial \phi}{\partial r}\right]_e \approx \frac{1}{r}\,\frac{\phi_2 - \phi_4}{2h} \qquad [2]$$

The second derivative is the rate of change of the first derivative. At point e the second derivative in the r direction is approximately

$$\left.\frac{\partial^2 \phi}{\partial r^2}\right]_e \approx \frac{1}{h}\left\{\left.\frac{\partial \phi}{\partial r}\right]_{P_2} - \left.\frac{\partial \phi}{\partial r}\right]_{P_4}\right\}$$

$$\frac{1}{h}\left[\frac{\phi_3 - \phi_0}{h} - \frac{\phi_0 - \phi_4}{h}\right] \qquad [3]$$

At point P_1 lying halfway between a and e the first derivative in the z direction is approximately

$$\left.\frac{\partial \phi}{\partial z}\right]_{P_1} \approx \frac{\phi_1 - \phi_0}{h}$$

Similarly at point P_3 the first derivative in the z direction is

$$\left.\frac{\partial \phi}{\partial z}\right]_{P_3} \approx \frac{\phi_0 - \phi_3}{h}$$

and the second derivative in the z direction evaluated at point e

$$\left.\frac{\partial^2 \phi}{\partial z^2}\right]_e \approx \frac{1}{h}\left\{\left.\frac{\partial \phi}{\partial z}\right]_{P_1} - \left.\frac{\partial \phi}{\partial z}\right]_{P_3}\right\}$$

$$\frac{1}{h}\left[\frac{\phi_1 - \phi_0}{h} - \frac{\phi_0 - \phi_3}{h}\right] \qquad [4]$$

Substituting [2], [3], and [4] in Laplace's equation [1],

$$\left.\frac{\partial^2 \phi}{\partial r^2}\right]_e + \left.\frac{1}{r}\frac{\partial \phi}{\partial r}\right]_e + \left.\frac{\partial^2 \phi}{\partial z^2}\right]_e$$

$$\frac{\phi_2 + \phi_4 - 2\phi_0}{h^2} + \frac{1}{r}\,\frac{\phi_2 - \phi_4}{2h} + \frac{\phi_1 + \phi_3 - 2\phi_0}{h^2} = 0$$

Taking h, the net interval, equal to one and the radial distance of e from the z axis equal to Rh, then after some rearranging, the following is obtained

$$\phi_0 = 1/8R\,[2\phi_1 + 2\phi_3 + (2R - 1)\,\phi_4 + (2R + 1)\,\phi_2] \qquad [5]$$

which is the basic improvement formula.

4 *Points on Axis.* Where points lie on the z axis, the $1/r \times \partial\phi/\partial r$ term in equation [1] causes some difficulty since $r = 0$. This difficulty is overcome by computing the $1/r \times \partial\phi/\partial r$ term at a point lying one-half of a net interval off of the axis. Referring to Fig. 2 at a point halfway between b and e

$$\frac{1}{r}\left.\frac{\partial \phi}{\partial r}\right] \approx \frac{1}{h/2}\left[\frac{\phi_2 - \phi_0}{h}\right]$$

The symmetrical distribution of hydraulic head around the z axis enables us to compute the $[\partial^2\phi/\partial r^2]$ e term. At a distance h to the left of point e lies another point having the same hydraulic head as point b. Equation [1] becomes

$$\phi_0 = 1/6\,[\phi_1 + \phi_3 + 4\phi_2] \qquad [6]$$

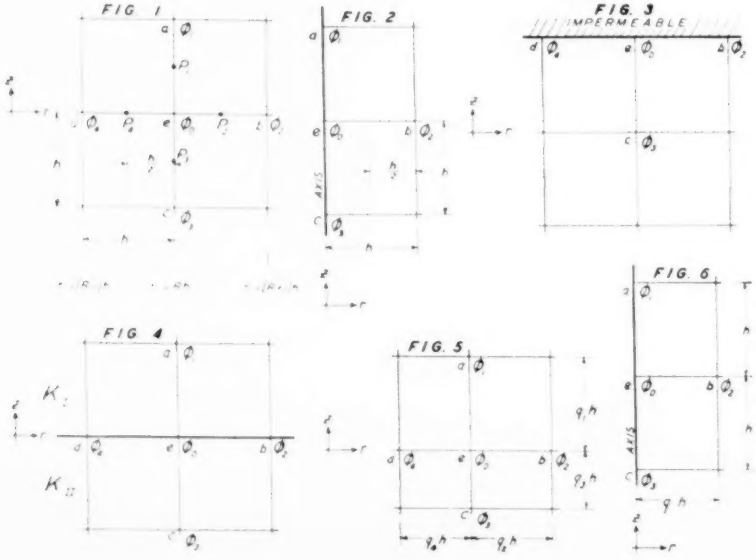
5 *Points on an Impermeable Boundary.* An impermeable boundary is a line of symmetry as well as a flow line. Referring to Fig. 3, the following equation can be derived for the hydraulic head at point e

$$\phi_0 = 1/8R\,[4\phi_1 + (2R - 1)\,\phi_4 + (2R + 1)\,\phi_2] \qquad [7]$$

6 *Points on an Interface Between Layers Having Different Permeability.* A special form of Laplace's equation is required for points lying on an interface between layers having different permeability and is as follows:

$$\frac{\partial}{\partial r}\left\{K\,\frac{\partial \phi}{\partial r}\right\} + \frac{1}{r}\,K\,\frac{\partial \phi}{\partial r} + \frac{\partial}{\partial z}\left\{K\,\frac{\partial \phi}{\partial z}\right\} = 0 \qquad [8]$$

where $K = F(r, z)$. If point e in Fig. 4 lies on the interface between two layers of permeability K_I and K_{II}, then the permeability between points a and e will be K_I and between e and c, K_{II}. Between points b and d, the permeability will approximate an average value of the two permeabilities and will approximately equal $(K_I + K_{II})/2$.



The derivation of the improvement formula is similar to that of equation [5]. The result is

$$\phi_o = \frac{4R K_1\phi_1 + 4R K_2\phi_3 + (2R+1)(K_1+K_2)\phi_2 + (2R-1)(K_1+K_2)\phi_4}{8R(K_1+K_2)}$$

7 *Unequal Net Spacing.* It is sometimes convenient or necessary to use a rectangular net having unequal net spacing as in Fig. 5. The procedures used to derive the basic improvement formula [5] can be modified to give the formula

$$\phi_o = \frac{1}{R(1/q_1 + 1/q_2 + 1/q_3 + 1/q_4)}\left[\frac{R\phi_1}{q_1} + \frac{R\phi_2}{q_2} + \left\{\frac{R}{q_3} + \frac{1}{q_3+q_4}\right\}\phi_3 + \left\{\frac{R}{q_4} - \frac{1}{q_3+q_4}\right\}\phi_4\right]$$

8 *Axis Point, Unequal Spacing in r Direction.* Referring to Fig. 6, the following equation is derived

$$\phi_o = \frac{q\phi_1 + q\phi_3 + 3\phi_2}{(3+2q)}$$

9 *Iterative Procedure for Obtaining Solution.* Although faster methods have been devised, the iterative procedure is the easiest to use by the untrained operator. The calculator proceeds from point to point on the net in a systematic order applying the improvement formula at each point to calculate a new improved value. The net is traversed repeatedly until further traverses give no change. The problem is then considered solved for the net spacing used.

As an example of the iterative procedure, consider Fig. 7, a very coarse net for the case of a gravity well with a flat water table. Points *a*, *b*, and *c* are boundary points on the water table and are assigned an arbitrary value of 1,000 for the hydraulic head. Since the water table remains static in a steady state, these values will remain constant. Points *d* and *g* are boundary points on the perforated section of the well casing and are assigned an arbitrary value of zero for the hydraulic head. The water level in the well is assumed to remain static so the hydraulic head on the perforated surface will not change. Points *e*, *f*, *h*, and *i* are interior points at which values of the hydraulic head are desired. A guess or estimate is made for the hydraulic head at these points. This initial guess (the top number in the column of numbers to the lower left of the point) must be improved to arrive at a better value. Equation [5] is used to find an improved value at *e* of ϕ'_e.

$$\phi'_e = \tfrac{1}{8}[(2)(1000) + 2(600) + (3)(800) + 1(0)] = 700$$

Point *f* lies on an impermeable boundary so equation [7] is used.

$$\phi'_f = 1/16[(4)(1000) + 4(700) + (8)(700)] = 775$$

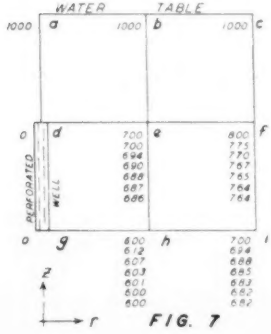


FIG. 7

Point *h* also lies on an impermeable boundary, so

$$\phi'_h = \tfrac{1}{8}[4(700) + 3(700) + 1(0)] = 612$$

and $\phi'_i = 1/16[8(775) + 8(612)] = 694$

Returning to point *e* and computing a second improved value

$$\phi''_e = \tfrac{1}{8}[(2)(1000) + 2(612) + 3(775) + 1(0)] = 694$$

The net is repeatedly traversed in this manner until the change in the value of hydraulic head at any point is less than one-half of one unit. The problem is then considered solved for the net spacing used. The accuracy depends on the number of significant figures used. No simple relationship exists between the accuracy of the final answer and the number of significant figures. It is advisable to use at least one more significant figure in the calculations than is desired in the final result.

10 *Other Procedures.* Southwell (7) uses a procedure which he calls the "relaxation method", a term sometimes applied to all numerical methods of solving differential equations. Residuals are computed at each point by a rearrangement of the improvement formulas. Equation [5] yields

$$\text{Residual} = \tfrac{1}{8}R[2R\phi_1 + 2R\phi_3 + (2R+1)\phi_2 + (2R-1)\phi_4] - \phi_0$$

As is evident from the above equation, a change in hydraulic head at any point will affect the residual at the four neighboring points as well as at the point in question. The operator works in areas of large residuals and reduces them by changing the values of hydraulic head. The procedure allows for flexibility and initiative on the part of the operator and a little practice soon discloses short-cut methods such as line and block relaxation that speed up the convergence of the problem. Southwell (7) discusses these short-cut methods in detail.

Another method of analysis attributed to Shortley et al (5) uses the difference between successive iterations. These differences are usually smaller than the values themselves, and Shortley devises special techniques for handling them.

NUMERICAL RESULTS

Four well problems of interest are solved here. The solutions are in the form of plots of isopiestic or equal hydraulic-head lines. Flow lines are indicated on two of the plots and are drawn in orthogonally to the isopiestic lines.

Case I. Gravity Well in Uniform Strata. The problem was solved using Southwell's relaxation technique, and Fig. 8

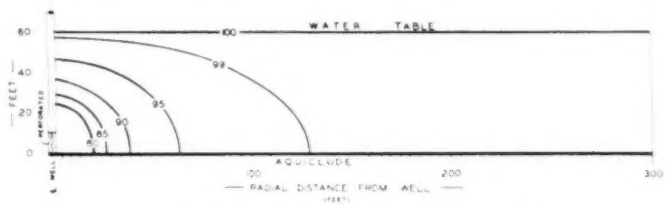


Fig. 8 Case I. Gravity well in uniform stratum

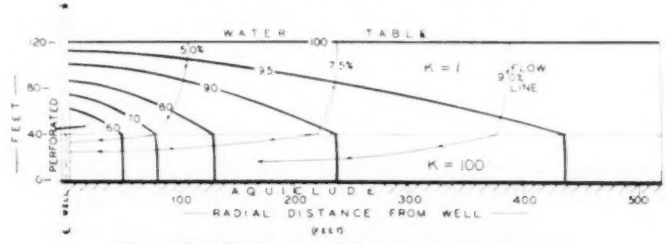


Fig. 9 Case II. Gravity well that pierces a gravel stratum

shows the isopiestic lines or lines of equal hydraulic head surrounding the well at the instant pumping starts. The pattern shown here is independent of the water level in the well as long as this water level is above the perforated portion of the casing. An examination of this figure shows that most of the water comes from within 100 ft of the well at the instant pumping starts. The water table will decline most rapidly near the well as has been shown by other workers[8] such as Babbitt and Caldwell (1).

Another feature of Fig. 8 is that, as might be expected, the greatest drop in hydraulic head is adjacent to the perforated section of the well. Since most of the fall in hydraulic head occurs in this region, its permeability would have a great influence on the flow into the well.

Case II. Gravity Well That Pierces a Gravel Stratum. The well is perforated only through the more permeable gravel stratum which is 100 times as permeable as the material above it. The solution, represented by Fig. 9, is valid only at the instant pumping starts. The sole source of water in this case is the region indicated in the drawing.

From the slope of the isopiestic lines we conclude that the water flows almost vertically down to the gravel aquifer (the term "gravel" is used for convenience; any two materials whose permeabilities differ by a factor of 100 would serve as well). It then travels laterally in the gravel to the well. Because of the relative flatness of the 95 isopiestic line we surmise that the cone of depression would be flatter than it would be for the previous case of a gravity well in material of uniform permeability.

Case III. A Partially Penetrating Well in a Confined Artesian Aquifer. This case has been studied analytically in a paper by Muskat (3) and represents a condition frequently encountered in the field. The solution is presented in Fig. 10.

This problem was originally solved with the 100 isopiestic line located 520 ft away from the center line of the well. This solution showed that at a distance from the well equal to twice the thickness of the aquifer, the isopiestic lines were essentially vertical and were a logarithmic function of the radius. In other words, at a distance from the well equal to twice the aquifer thickness, the effect of the partially penetrating well on the hydraulic head was the same as for a well which completely penetrated the aquifer.

The 100 isopiestic line was then moved in to a distance of 200 ft from the well and the problem solved using seven significant figures with a net spacing of 10 ft.

The significance of the location of the 100 isopiestic line is that at greater radii the hydraulic head is a logarithmic function of the radius. The radial extent of the aquifer is not limited by the 100 isopiestic.

Case IV. An Artesian Well Which Pierces Two Separate Aquifers. Fig. 11 is the solution to the case where a well

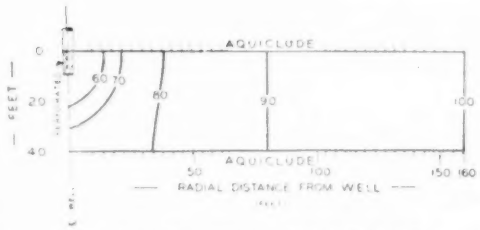


Fig. 10. A partially penetrating well in a confined aquifer

pierces two separate aquifers, the top aquifer being at lower hydraulic head than the lower aquifer. Both aquifers have the same permeability and are separated by a layer of material having permeability equal to 1/100 that of the aquifers. The well is perforated only through the more permeable aquifers.

An examination of the refraction angles of the isopiestic lines at the interface between the layers of different permeability indicates that the central region of lower permeability acts essentially as though it were impermeable. A similar relationship was observed by Luthin and Gaskell (2) for the case of tile drainage of layered soils.

Since the central portion is essentially impermeable, the distribution of hydraulic head in each aquifer is a logarithmic function of the radial distance from the well.

SUMMARY

The methods of numerical analysis are used to obtain steady state solutions of Laplace's equation in cylindrical coordinates. Formulas are developed for problems having complicated geometry, variable permeability and various boundary conditions. The flow of water through aquifers into wells is analyzed for four cases of practical interest. Two of the cases examined are for gravity wells and two are for artesian wells.

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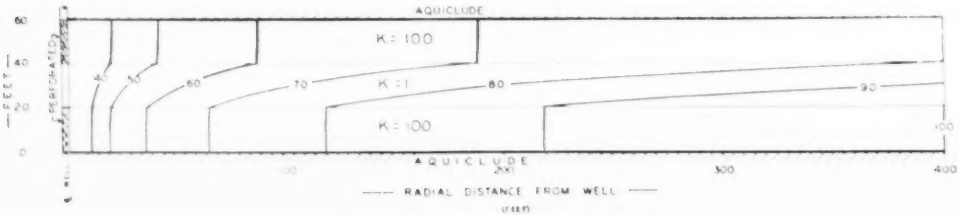

Fig. 11. An artesian well which pierces two separate aquifers

Simplified Procedure for the Measurement and Computation of Soil Permeability Below the Water Table

By H. P. Johnson, R. K. Frevert, and D. D. Evans
ASSOC. MEMBER ASAE MEMBER ASAE

RECENT research in the field of drainage has placed a considerable emphasis on methods of determining permeability. Laboratory methods have not been satisfactory because of the effects of moisture variation, air, and bacterial action as well as the difficulty of obtaining undisturbed samples. However, practical field methods have been developed which it is hoped will aid in securing better data for the design of drainage systems. These field methods have several distinct advantages over laboratory methods. The "sample" is larger and the soil is not disturbed except for possibly some puddling caused by augering instruments. The fluid used is soil water and not tap or distilled water.

Field measurements of permeability may be made by the auger-hole method which utilizes a relatively large "sample" volume and provides a composite permeability coefficient for the portion of the hole below the water table. With this method, very little time is required to prepare holes for readings. One disadvantage of this method is that if several strata are encountered the effect of one may dominate.

Another method involving the use of a piezometer tube makes possible the determination of permeability at greater depths below the water table. The permeability of any soil stratum greater than a foot in thickness may be measured using this procedure.

Both of these methods accent the horizontal permeability, which may differ from the vertical permeability, and require the presence of a water table. The position of the water table must be considered in selecting positions for permeability tests with either the auger-hole or piezometer-tube method. In subsurface drained land, the most suitable accessible positions are those along a line midway between the tile lines where the water table is highest.

This paper was prepared expressly for AGRICULTURAL ENGINEERING, and is a contribution of the ASAE Subcommittee on Depth and Spacing of Tile Drains. It has been approved for publication as Journal Paper No. J-2048 of the Iowa Agricultural Experiment Station, Projects 1003 and 998.

The authors: H. P. JOHNSON and R. K. FREVERT, respectively, research associate and professor of agricultural engineering, and D. D. EVANS, research associate in agronomy (soils), Iowa State College (Ames).

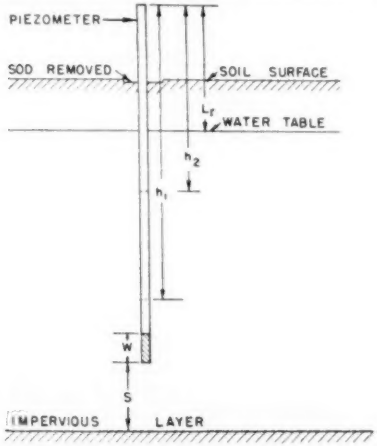

Fig. 1 Diagram of method followed in permeability determination by use of the piezometer tube

The following descriptions of these two methods of permeability determination are essentially those given by Luthin and Kirkham (5)* and Van Bavel and Kirkham (7) in 1949. These methods were developments of work reported by Frevert and Kirkham (2) in 1948 and the original theory proposed by Kirkham (3) in 1945. Further discussion of the relative merits of the two methods may be found in work reported by Reeve and Kirkham (6).

THE PIEZOMETER METHOD

Procedure. A hole 1 15/16 in in diameter is bored to a depth of 6 in after trash and surface sod have been removed from the location chosen for a measurement. A sharpened section of 2-in (inside diameter) thin-walled electrical conduit is driven axially into the hole to a depth of 5 in using light blows from a maul. To prevent damage to the top of the tube it is desirable to use a driving head. The 1 15/16-in soil auger is then inserted into the tube and the soil is removed to a depth 6 in below the bottom of the tube. The tube is again driven 5 in deeper. This procedure is continued until the tube point is at the depth desired for measurement. A cavity, 4 in in length and 1 15/16 in in diameter, is then carefully augered below the bottom end of the tube. A stop may be attached to the auger shaft to make contact with the top of the tube when the cavity is drilled to proper depth.

The water seeping into the cavity is then pumped out two or three times to remove the effect of puddled soil on the cavity walls. To facilitate this, a hose attached to a small pitcher pump is inserted to the tube bottom. Reproducibility of results from an individual hole indicates that puddling effects have been minimized.

Soil water is then allowed to rise in the tube. The equilibrium water level is determined. In highly permeable soils as little as a few seconds may be required for the water table to reach equilibrium; in tight clay soils a longer time is required. The necessary data are obtained in the following manner. (Refer to Fig. 1.) After the water level in the tube has reached equilibrium, the measuring apparatus† (4) is placed on top of the tube and the probe is lowered until the water level is reached as indicated by a sudden deflection of the milliammeter. This position is recorded as depth to the water table from top of pipe, L_f. The measuring apparatus is then removed, most of the water pumped from the hole, and the measuring device replaced. The probe is lowered into the tube until it touches the water surface. This position, h_1, is recorded along with t_1, the time at which the probe touched the surface. This initial time would be zero if a stop watch is used. The probe is then raised. The distance the probe is raised may vary but at least 0.1 ft is recommended even in tight clay. The water is allowed to rise in the tube until the milliammeter is deflected. The time, t_2, is then recorded along with the second probe position, h_2. At least three increments of rise and time should be taken in each tube at each position.

After the readings are taken the tubes may be removed with a modified Veihmeyer soil tube jack. This jack is manufactured by the Robert McNavin Machine Works, 1431 Second St., Sacramento, Calif.

*Numbers in parentheses refer to the appended references.

†This type of measuring apparatus consists of a platform and pipe housing placed on a piezometer tube or probe stand through which a flexible insulated electrical conductor with exposed end is lowered to make contact with the water surface. The platform supports a fishing reel on which the conductor is wound, a battery, resistors and a milliammeter. The circuit is arranged to deflect the milliammeter when the exposed end of the conductor touches the water surface.

Conversion of Observed Data to Permeability. The expression for the permeability from data obtained by the piezometer method may be written as follows:

$$K = \frac{\pi R^2 [ln (h_1 - L_e)/(h_2 - L_e)]}{A (t_2 - t_1)} \quad . \quad . \quad . \quad [1]$$

where R = inside radius of tube (inches)
ln = natural logarithm
A = a factor in inches which is a function of the geometry of the flow system into the cavity below the tube
L_e = distance from top of pipe to water table (feet)
h_1 = distance (feet) from top of pipe to water at time t_1 (seconds)
h_2 = distance (feet) from top of pipe to water at time t_2 (seconds)
K = permeability in inches per second

(NOTE: L_e, h_1, h_2 may be in any units as long as the same units are used.)

If the size of the cavity and piezometer tube used are the same as those recommended, π, R^2 and A in equation [1] may be combined as a constant. The A factor for a cavity 4 in long and 1 15/16 in in diameter is 17 in, if s, the distance from the bottom of the cavity to a possible impermeable layer, and the length of pipe below the water table are greater than 8 in. An error of less than ±8 per cent is introduced if the length of pipe below the water table is equal to or greater than $\frac{1}{2}W$, and s is equal to or greater than $\frac{1}{2}W$.

Since these limiting conditions are seldom encountered, it is assumed in this presentation that the A factor is constant. The original article may be referred to for other cases. By combining π, R^2 and A and converting seconds to hours, we get

$$K = \frac{625 [ln (h_1 - L_e)/(h_2 - L_e)]}{t_2 - t_1} \quad . \quad . \quad . \quad [2]$$

the units for K being in inches per hour. Fig. 2 is a graphic presentation of equation [2] and may be used to solve for the coefficient of permeability.

The following example may be used as a guide in the use of the graph.

Assume $L_e = 1.25$ ft, $h_1 = 3.22$ ft, $h_2 = 2.39$ ft, $t_1 = 0$ sec, $t_2 = 17$ sec.

Then $\frac{h_1 - L_e}{h_2 - L_e} = \frac{3.22 - 1.25}{2.39 - 1.25} = 1.73$

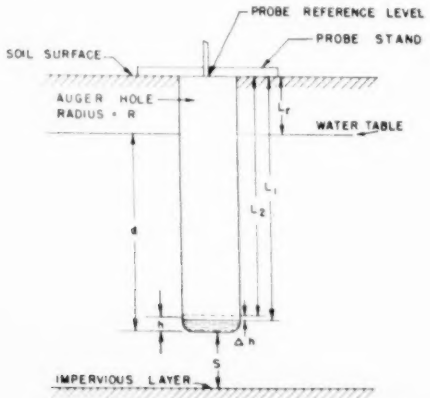

Fig. 3 Diagram of method followed in permeability determination by the auger hole method

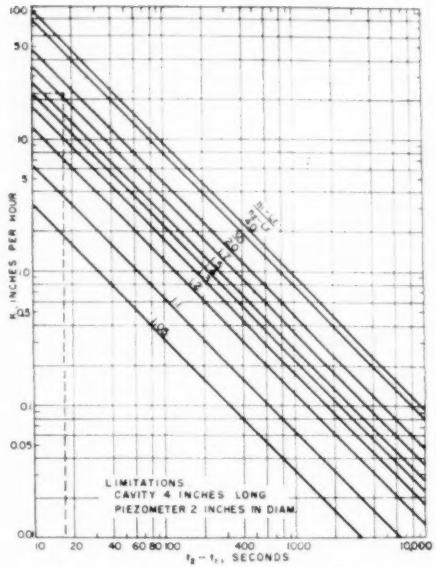

Fig. 2 Graph for solution for coefficient of permeability

After solving for the ratio of $(h_1 - L_e)/(h_2 - L_e)$, select a line on the graph which most nearly represents the ratio. This line will probably have to be selected by interpolation. Then using the result of $t_2 - t_1 = 17$ sec, move upward from the abscissa (time) until the ratio line is intercepted. By moving to the ordinate (K) from the point of interception, the permeability may be read directly as 22 iph.

For quick calculations in the field of the permeability by the piezometer method, an approximate equation can be de-

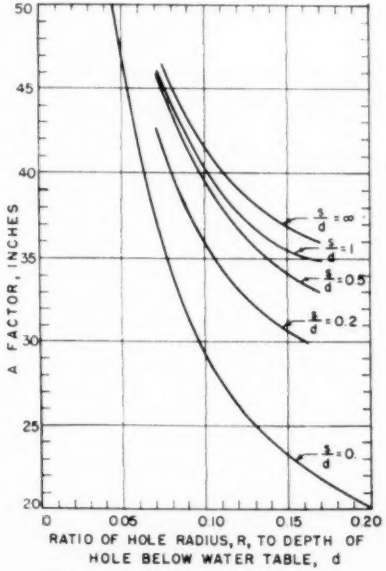

Fig. 4 Graph for use in finding the A factor

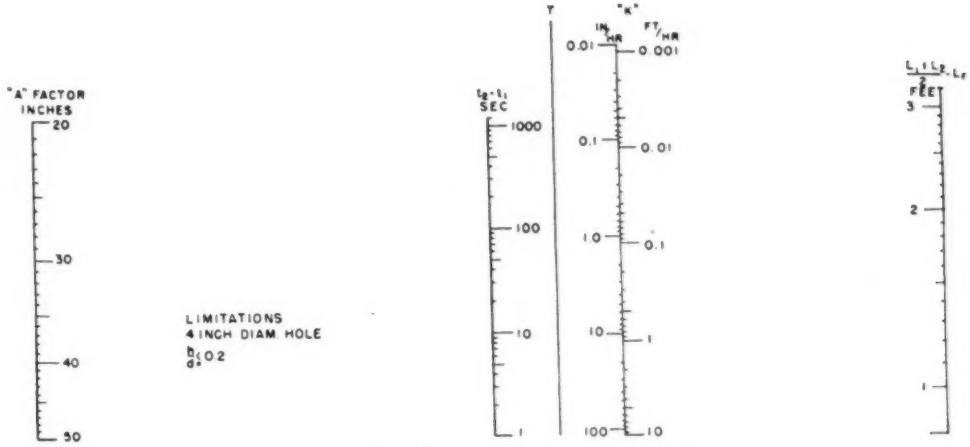

Fig. 5. Nomograph for more rapid computation of permeability

rived which is easy to remember and gives a good estimate of K. This equation

$$K = 665 \frac{\Delta h}{\Delta t} \frac{1}{\text{Average head}}$$

$$\text{or } K = \frac{1330\,(h_1 - h_2)}{(t_2 - t_1)\,(h_1 + h_2 - 2L_r)}$$

will give K in inches per hour if h and L_r are in feet and t is in seconds, assuming again that $R = 2$ in and $W = 4$ in. The percentage error using this equation will be less than 1 per cent if $\Delta h \leq 0.2$ and the average head ≥ 0.5 ft.

THE AUGER-HOLE METHOD

Procedure. Using a 4-in-diameter auger, a hole is bored to a depth of 12 to 30 in below the water table. (The depth is limited by the A factor as presented in Fig. 4.)

The depth of the hole would depend to some extent on the depth at which a permeability reading is desired even though this results in a composite permeability. Seepage water is pumped from the hole two or three times to minimize the effect of puddled soil on the walls. The water table is then allowed to come to equilibrium, which may require as long as three days in very impermeable soil.

The same measuring probe may be used with this method as with the piezometer-tube method if a stand is provided. The measuring probe and stand are placed solidly over the center of the hole. The probe is lowered the distance L_1 to the water table (Fig. 3); this distance is recorded. The water is then pumped from the hole and the probe is lowered to the water surface about 0.1 to 0.2 ft from the bottom of the hole. The distance L_1 and the time t_1, when the measurement is made, are recorded. Then the probe is raised a distance Δh, which should be between 0.01 ft and 0.1 ft depending on soil permeability. The water is then permitted to rise the distance Δh to L_2. When the water strikes the probe, the time, t_2, is recorded. The probe is raised an equal distance, Δh, again and the same procedure is followed. Three or four readings are taken over successive equal increments of rise of the water in the hole, and the time at the end of each increment is recorded. The time required for equal increments of rise should be nearly the same. All readings should be taken before the water rises to the level where $h/d = 0.2$, where h is the average height of water above the bottom of the hole during any increment of rise and d is depth of hole below the water table. This facilitates the use of the formulas and graph which follow. At least three observations of rate of rise should be made in each hole.

Conversion of Observed Data to Permeability. The expression for permeability may be written as follows:

$$K = \frac{(L_1 - L_2) \pi R^2}{(t_2 - t_1)\,[(L_2 + L_1)/2 - L_r]\,A}$$

where K = coefficient of permeability in inches per hour

$L_1 - L_2 = \Delta h$ = increment of rise of water in hole (feet)

$t_2 - t_1 = \Delta t$ = increment of time (hours) required for length of rise, Δh

R = radius of hole (inches)

$(L_2 + L_1)/2 - L_r$ = average distance (feet) of water level in hole below water table during time, Δt

A = factor in inches which is a constant depending on R, d, h, and s, where s = distance of impermeable layer below bottom of hole and h = average depth of water in hole in inches during Δt.

The A factor may be found by referring to Fig. 4. The curve selected will depend on the ratio of s/d as shown in Fig. 3‡. The permeability may be computed using the above formula.

In order to make more rapid computations possible, the nomograph (Fig. 5) was constructed for Δh of 0.1 ft and an auger diameter of 4 in. If the height of the water is recorded in feet, and the radius of the hole and the A factor are in inches, the formula will give the permeability in terms of inches per hour. Care must be taken, however, to use the same units for R and d in determining the ratio R/d. Since most engineering measuring equipment is calibrated in feet, an example will be given in feet. Assume that $t_2 - t_1 = 30$ sec, $L_1 = 2.48$ ft, $L_2 = 2.46$ ft, $L_r = 0.83$ ft, $d = 1.80$ ft, and $s/d = 1$. Then the A factor is found to be 42 in for a hole with a radius of 2 in. Using a straightedge, find the line determined by an A factor of 42 in and a time $(t_2 - t_1)$ of 30 sec. Mark the point where the line intersects the pivot line, T. Then using the point on the pivot line, T, and the computed $(L_1 + L_2)/2 - L_r$ of 1.64 ft, the permeability can be

‡The case for $s/d = \infty$ was found by the graphic method. By plotting the A factor as the ordinate and the reciprocal of s/d as the abscissa on semi-logarithmic paper and using the curves $s/d = 0.2$, $s/d = 0.5$ and $s/d = 1.0$, points for a straight line may be obtained from one ratio of R/d. By plotting curves for several values of R/d and extrapolating these curves to the ordinate axis, points for a curve for $s/d = \infty$ were obtained. The values compare favorably with those found by Ernst (1) who computed the case of $s/d = \infty$ by the relaxation method.

read as 2.3 iph, based on 0.1 ft rise. The nomograph is designed for an increment of rise of 0.1 ft; hence, if an increment of 0.02 ft was used, the permeability would be one-fifth of that read from the nomograph, or 0.46 iph.

If a degree of accuracy greater than that obtainable by the graphs is desired, the original equations may be used. When compared to the calculated value, the error in reading the nomograph should be less than 8 per cent, while the error in reading the graph developed for the piezometer method should be less than 4 per cent. In most cases greater accuracy has no added significance in permeability computations.

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"Mulch and Fertilizer"

TO THE EDITOR

THE concluding statement on the editorial page of AGRICULTURAL ENGINEERING for February suggests that you might be interested in other facts and theories related to the tillage method used by Dr. Scarseth. I presume your editorial relates to facts reported in "Country Gentleman" for February.

The slit method of tillage is essentially the method about which I had reached conclusions by January, 1945, and which was inherent in my design for a sod-inverter tillage machine and planter which was reduced to drawings March, 1945. Experiments involving the elements of this tillage method were carried out in my garden at Racine, Wisconsin, during the years 1943, 1944, and 1945.

The method I proposed as applied to corn production was as follows:

1. Leave approximately a 20-in wide sod strip between the rows.
2. Cut two 9-in wide furrows, not more than 8 in deep, and replace them inverted into the space from which they came.
3. Drop seed and fertilizer simultaneous with the above operation.

This method, the proposed machinery for it, as well as the theories involved, were explained in detail to L. W. Garver of the Massey-Harris Co. late in 1945.

By arrangement with the B. F. Avery Company, the above method and machines were described and specifically excluded from the general terms of the patent agreement signed and witnessed at the time of my employment in January, 1946.

At the Chicago meeting of the American Society of Agricultural Engineers in 1946, I told E. W. Lehmann of my work and proposals outlined above. He then informed me of the preliminary results obtained by Dr. Bartlson's department (University of Illinois) which were publicly released a week or so before. There followed an exchange of ideas by letters now on file.

Aside from the specific proposals made for growing corn, the following ideas were also recorded in my notes, 1943-1945:

1. Expenditure of energy on the soil should be confined to the top 5 in of the soil profile.
2. Water requirement of plants may be greatly reduced by increased soil fertility.
3. Seedbed preparation should produce a hygroscopic gradient in the soil with the greatest attraction for water at the evaporating surface.
4. Seedbed preparation should produce the conditions of maximum evaporating loss of water over the growing season.
5. The crop rotation should be carried on at the level of ecological balance found in old meadows. Thus corn grown by the sod inversion method allows the community relationship of plant and animal life to persist largely unchanged from year to year through succeeding rotations.

The role of available nitrogen in eliminating competition between plants has been demonstrated by Dr. Bray, and is probably his distinct contribution to the method of growing corn where unlimited undergrowth is permitted.

In my opinion, the experiments at the University of Illinois, starting with the summer of 1946, are proof that my proposals of early 1945 were basically correct.

ELMER W. HENRY

Product designer, B. F. Avery Division
Minneapolis-Moline Co.

"Evaluation of Air Resistance to Freely Falling Drops of Water"

A CORRECTION

By Robert L. Green

AN ERROR in the mathematics of the above titled paper published in AGRICULTURAL ENGINEERING for January, 1952 (page 28), has been called to the author's attention. This error in turn affects the values of Table 1 (shown corrected below), and hence the evaluation of K. The correct solution of equation [1] follows:

$$M\frac{dv}{dt} = Mg - Kv^2$$

$$\frac{dv}{dt} + \frac{Kv^2}{M} = g$$

$$Ve^{(K/M)t} = \int ge^{(K/M)t}\,dt = \frac{M}{K}ge^{(K/M)t} + C$$

$$v = \frac{Mg}{K} + Ce^{-(K/M)t}$$

At time $t = \infty$, $v = V_t$, terminal velocity, $Ce^{-(K/M)t} = 0$

then $V_t = \frac{Mg}{K}$

and $K = \frac{Mg}{V_t^2}$

Substituting Law's experimental data for a 1.17 mm drop,

$$K = \frac{(0.00084)\ (980)}{460} = 0.00179$$

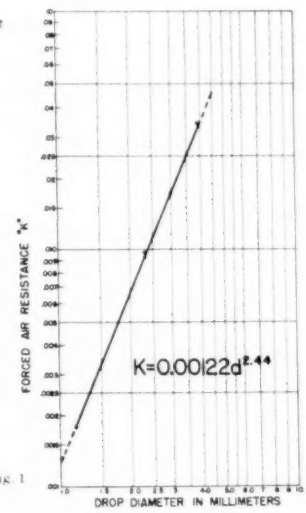

FIG. 1

TABLE 1
(corrected)

Drop diameter, in mm	Minimum fall distance to attain V_t, in meters	V_t, cm/sec	m, in g	K
1.17	2.2+	460	0.00084	0.00179
2.32	5.0+	666	0.00654	0.00962
2.34	5.0+	705	0.00671	0.00933
3.00	7.2+	803	0.01412	0.01725
3.92	7.8+	885	0.03154	0.03492

The plotting of the data in Table 1 on log-log paper as shown in Fig. 1 (corrected) yields the relation

$K = 0.00122d^{2.44}$ with d = drop diameter in millimeters.

Use of Soil Porosity for Water Conservation

By Lloyd L. Harrold
MEMBER ASAE

ON MUCH of the farm land of our country there is within a few feet of the ground surface a great water-storage reservoir which, at times, is capable of absorbing large quantities of rainfall. Water-conservation plans, to be comprehensive, must take into consideration the possibility of an increase in the use of the water-storage capacity in the soil reservoir. In order to make the proper use of this reservoir, the conservation job must begin where the raindrop falls. It is the purpose of this paper to illustrate for the soils on the Coshocton Experiment Station how inadequately such storage capacity is being used in certain seasons and to point out possible means of making more use of it. It is to be recognized at the start, however, that at times slowly permeable soils generally retain too much moisture for proper aeration and root development. In such cases an increase of infiltration and water absorption in wet seasons is undesirable. Yet, in these same soils, there are times when it is most desirable to increase the water content — that is, when there is insufficient moisture to sustain crop growth. In general, it can be said that pore space in the better drained soils can be used over and over again for water storage whereas poorly drained soils provide this storage only once over a long period.

The quantity of water in the pores of this soil reservoir — a factor influencing the rate of water absorption — is constantly changing. This soil water may be depleting by draining to lower depths, evaporating to the atmosphere, or transpiring by vegetation. Or, it may be increasing by infiltration of rain water or melted snow or by the absorption of moisture condensed from the atmosphere. Dreibelbis (1)* pointed out the seasons when the soil pores are mostly filled with water and the seasons when there is normally very little water in the soil (Fig. 1). There are soils with many large pores which drain water rapidly and there are soils with pores mostly of small size which do not drain.

Along with all these variations in the soil characteristics and climate, there are many differences in the effect of agricultural management on the soil structure — that is, the arrangement of soil granules, pore size distribution, and the like.

Page and Willard (2) in 1946 wrote: "The physical condition of soil has often been considered to be an inherent property over which we have little or no control. Experience and research show, however, that physical properties of soils do change and it is apparent that cultural practices have a profound effect upon them." We cannot afford to overlook this phase of land management for water and soil conservation programs.

An examination of the top curve of Fig. 1 reveals for a 40-in depth a period of soil-moisture depletion from mid-May into early September. A depth of 40 in was used as it comprised most of the root zone of rotation crops. Although this trend is quite typical, perhaps the rate of depletion in July and August was excessive due to the subnormal amounts of rainfall in these two months. If we assume that this 40-in profile is capable of absorbing water up to a 14-in total capacity (peak reached in March), then capacity deficiencies can be computed for other periods of the year. For example, in June, 1945, the reservoir in the 40-in depth was nearly 4 in short of capacity. Yet from the June rainfall of 4 in there was 1 in of rain water lost in runoff.

By the first of September, the graph shows that the soil reservoir in the 40-in depth was over 9 in short of capacity. September rainfall of about 9½ in could have been entirely taken up by this reservoir, yet there was over 2 in of rain water lost in runoff. There have been many individual storm periods when the soil reservoir was used even less than this. For example, with over 5 in of reservoir capacity unfilled before the July 28, 1950, storm, there was 0.47 in of runoff from a 1.11 in rainfall on cornland. Yes, and there was over a ton of soil loss per acre in this runoff water from contour cornland. This same storm caused over four tons of soil loss from each acre of sloping row — or off-contour cornland. An examination of the hydrologic characteristics of the soil profile will reveal the reasons why so little of the soil reservoir was used in this and other instances. It will also direct attention to possible means of diverting more storm rainfall into this internal reservoir.

There are numerous soil factors influencing the movement of water into and through the soil profile. These factors appear to differ in various horizons of most soil profiles. On the Coshocton Experiment Station, the Muskingum silt loam — a residual soil of shale origin — has a fairly permeable topsoil of 7-in depth and a much less permeable subsoil. The volume of non-capillary pores in this topsoil is about 23 per cent and that in the subsoil 14 per cent according to Schiff and Dreibelbis (3). These variations are largely the cause for different infiltration capacity rates as illustrated by Schiff and Dreibelbis (4) and summarized in this paper in Table 1.

In clean-cultivated fields it has not always been possible to make use of the high infiltration capacity rates for the topsoil as shown in Table 1. These data relate to a sod cover on a soil surface well aggregated with large soil crumbs and good-sized openings or pores. When raindrops fall directly on bare soil, many of the larger soil crumbs or aggregates are

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AUTHOR'S NOTE: The author gratefully acknowledges the work of F. R. Dreibelbis and R. E. Youker in providing data on soil moisture, soil pore space, and soil aggregation.

*Numbers in parentheses refer to the appended references.

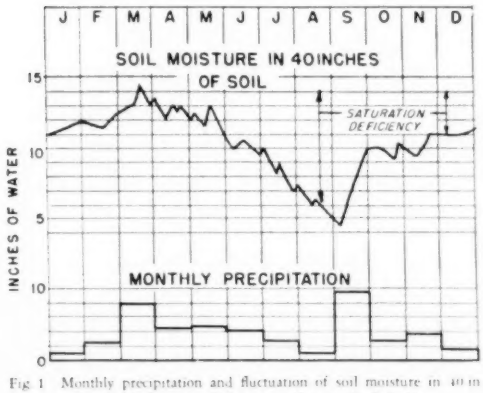

Fig. 1 Monthly precipitation and fluctuation of soil moisture in 40 in of soil, Muskingum silt loam, rotation cornland, 1945.

TABLE 1 Infiltration capacity rates for various moisture contents, Muskingum silt loam (4)

Soil moisture per inch depth of soil, in	Air space* per inch depth of soil, in	Infiltration capacity rates Topsoil, iph	Subsoil, iph
0.05	0.45	9.0	0.75
.20	.30	6.0	.50
.40	.10	2.0	.10
.45	.05	1.0	.08

*In air space of 0.45 inch per inch depth of soil, there can be taken up 0.45 inch of water before complete saturation is reached.

broken down into fine particles. As these settle into the pores there is less channel space through which water can penetrate into the soil. This process of soil structure deterioration commonly referred to as "surface sealing" is normally confined to a very shallow depth. In some high-intensity storms having large raindrops, the soil pores have been almost completely closed within a period of a few minutes. Aggregate analysis of soil samples taken in a cornfield in September, 1950, (Table 2) show the result of this raindrop splash and other destructive forces.

TABLE 2. Surface sealing of soil in contour cornland under normal treatment

Sampled September 1950	Soil depth, in.	Aggregates > 0.2 mm. per cent	Total Fines per cent
In row	0-1	19	67
	1-4	23	64
Between row	0-1	13	70
	1-4	16	67

It is evident from the data in Table 2 that more of the soil particles in the surface inch were of fine size than depth of 1 to 4 in. It is also apparent that there were more fines in between the row than in the row itself. Soil cores obtained at the end of the 1947 corn season of the 0- to 3-in. depth in between the rows were obtained to determine infiltration capacity for normally treated cornfields. Samples were also taken in a mulch cornfield where surface sealing was not as serious. Infiltration determinations made on these two sets of soil cores appear in Table 3. They show that the surface sealing in the normal cornfield resulted in a definite reduction in permeability.

TABLE 3. Permeability and plant residue content of surface soil in clean plowed and mulch cornfields

Treatment	Permeability rate, iph	Plant residues per acre inch of soil, lb.
Clean plowed (normal)	1.1	40
Mulch	5.0	260

NOTE: Data are average of four samples, 0- to 3-in. depth.

A reduction of infiltration at the land's surface has, many times in the growing season, resulted in runoff and erosion when much of the soil-water reservoir was unused. Fig. 2 illustrates on two magnified soil profiles (A) unsealed soil surface with 7-in. topsoil saturated and unused pores at 8 to 10 in. deep, and (B) sealed surface with saturation deficiencies an inch or so below the surface. The latter condition, for which soil condition and permeability data are given in Tables 2 and 3, greatly affects surface runoff and erosion as well as the ability to make use of the soil reservoir. Field measurements of soil moisture in per cent by volume provide data on the volume of available water-storage space at various depths in this soil reservoir prior to storms. Field rainfall and runoff data show how much of this storage capacity was used. These data for two large storms in 1950 (Table 4) illustrate that on July 28 there should have been no runoff and the September 1 runoff should have been much less than actual, provided that all the available soil reservoir had been used.

TABLE 4. Use of pore space for water conservation on contour corn watershed, storms of July 28 and September 1, 1950

Item	July 28	September 1
Rainfall	1.11 in.	1.52 in.
Runoff	.47	2.62
Difference (infiltration)	.64	1.70
Soil loss per acre	1.2 tons	1.5 tons
Saturation deficiency in 7 in. topsoil:		
Before storm	2.79	2.79
After storm	2.15	1.09
If all pores in 7 in. topsoil had been used:		
Runoff	0	1.62
Soil loss	0	0.8 (estim.)

NOTE: Watershed area = 0.65 acre on 11.5 per cent land slope, corn on contour with grass waterway.

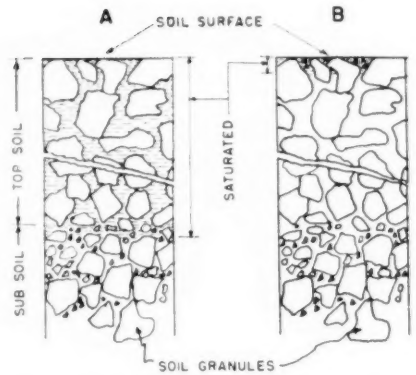

FIG. 2. Magnified soil profiles. A, surface unsealed, topsoil saturated, soil and water losses occur with unused reservoir 8 to 10 in. below surface. B, surface sealed, soil and water losses occur with unused reservoir an inch or so below the surface.

In a mulch corn watershed, the entire pore space in the topsoil was used. Likewise, in the sod watershed where the soil surface remained porous, it was possible to make use of the soil reservoir for water absorption.

It is to be noted that in the presentation to this point attention has been directed to the use of the soil reservoir only in the topsoil — normally 7 in. deep for Muskingum silt loam soil — of crop land in this area. A review of the data in Table 1 will give the reason for this, namely, the relatively high permeability rates as contrasted to those of the subsoil lying beneath this 7-in. depth. Unless the land surface is treated in such a way as to prevent sealing to a significant degree, the rapid water transmission ability of the topsoil cannot be utilized, as described before. This problem and its solution has first priority for clean cultivated cropland having soils susceptible to sealing.

Most of the methods for the reduction of surface sealing under consideration at this experiment station involve mulches, non-competitive organic residues remaining from sod preceding corn and/or additive organic materials. Some methods and results were reported earlier by Harrold and Dreibelbis (5). Methods and comments (in parentheses) are given below:

1. Disking sod, using a heavy duty disk.

(If kill of sod can be accomplished in about two operations, this method will provide a good quantity of mulch in the surface and yet mix some to depths of 6 to 8 in. Add weight to planter for needed compaction.)

2. Plowing sod, turning slice on edge followed two weeks later by field cultivator 4 to 5 in. deep to pull up plant residues for surface mulch.

(The plowing job usually gets a good kill on the sod but the field cultivator apparently does not pull up as much plant-residue material as is desired for a good mulch. Add weight to planter for needed compaction.)

3. Normal plowing, fitting, and planting followed by good application of strawy manure.

(Manure can be applied either before or after corn comes up. On steep land the spreader tends to drift downhill and the wheels occasionally ride on the corn row. Manure applied just after the corn came up appeared to be more effective as a mulch throughout the entire season. The earlier application disappeared too soon. The manure did not create a weed problem, neither was it difficult to cultivate through.)

4. Normal plowing, fitting, and planting. Following the last cultivation apply a mulch.

(This mulch was spoiled hay — the first cutting in the field was wet by several rains. It was raked up, dumped along the corn strip and spread by hand in the corn area. This

mulch protected the soil and saved moisture as indicated in Table 5.)

TABLE 5.—Spoiled hay mulch in cornland improved soil moisture content in August drought (Crop-yield increases resulted)

Soil depth, in	Available moisture			Corn yield per acre		
	Unmulched, per cent‡	Mulched		Unmulched, bu	Mulched	
		Crusted*, per cent‡	Broken†, per cent‡		Crusted*, bu	Broken†, bu
0-7	8	16	20	94	99	110
7-14	12	20	19			

*Mulch applied on crusted soil surface.
†Crust broken up before mulch was applied.
‡Per cent by volume.

5. Forage harvester blowing chopped hay onto corn strips at lay-by time, or before it desirable.

(This procedure has not yet been tried but it provides a possible means of applying a mulch on cornland for soil and water conservation when water demand by crops is great.)

6. Plow 3 in deep; with subsweep loosening soil to 9-in depth in same operation.

(Shallow plow inverts thin sod strip. Fitting operation of disking and drag harrow have prepared a mulch seedbed. Subsoiling provides a loose root bed. It has been suggested that a heavy-duty rotary hoe pulled at about a 15-deg skew would shred the inverted sod strips much better than a disk and leave more mulch on top. This will be tried.)

The Ohio State University is engaged in studies involving the use of chemicals applied to the soil surface to aid in stabilizing soil aggregates. Preliminary results show that bare soil treated with this material has resisted surface sealing and maintained good-sized pores, resulting in high infiltration rates at the surface. This process appears to be too costly at the present for widespread farm application. Conditions may, however, change so as to bring this method within the realm of practicability.

Along with the "save-the-surface" program of mulch and other treatments of clean cultivated fields, there is the problem of increasing the soil depth to which infiltrated water can move rapidly. It is evident from the data in Table 1 that the subsoil absorbs storm rainfall much slower than the topsoil. Thus when the infiltrated water fills the pores in the topsoil reservoir, surface runoff and erosion occur — although there are unsaturated pores within the subsoil root zone (Fig. 2-A). This condition prevails in pastures and rotation meadows as well as in rotation cornland.

Ten years of conservation practices, using alfalfa-timothy rotation meadows, on a watershed having a slowly permeable subsoil have not yet had a measurable effect on its ability to take up and pass water to lower depths. Shattering this subsoil to depths of 18 in had no lasting benefit. Observations 10 months after fall shattering and spring wetting showed that the weight per unit of soil volume differed little from that before the operation. For a time after subsoil shattering there appears to be some benefit as shown in Table 6. Volume weight was lowered and permeability was improved.

TABLE 6.—Effect of subsoiling on volume weight and permeability at the 7- to 10-in, 1951

Date, 1951	Item	Plowed, normal	Plowed 4 in deep plus subsoiling 9 in deep
April 18	Volume-weight	1.48	1.51
April 27	Plowing operation	x	x
June 1	Volume-weight	1.52	1.35
June 1	Percolation rate	0.97 iph	4.2 iph

NOTE: Data are average of six samples.

Work of D. D. Smith at the Soil Conservation Service Experiment Station at McCredie, Mo. (6) reported that subsoiling plus deep applications of lime and fertilizer increased the root penetration into claypans. There were also a few observations to indicate that runoff may, in time, be reduced as a result of this practice. A similar process has been tried at the Coshocton Station for the past two years without any noticeable effect yet. This is not conclusive as root response and changes in soil aggregation and pore size distribution will likely require more than a few years.

Attempts have also been made at Coshocton to accelerate the accumulation of organic matter in the subsoil by plowing down sod to a depth of 10 in. Normal plow depth is 7 in. If the topsoil depth could be, in effect, increased a few more inches, the depth to which water would move rapidly would be increased and a greater volume of soil reservoir made quickly available. For example, there was available in pores of 7 in of topsoil 2.70 in of water-reservoir capacity prior to the September 1, 1950, storm (Table 1). If there was, in effect, 10 in of topsoil, there would have been made quickly available 3.86 in of reservoir capacity. Resulting runoff and erosion could thus be reduced.

When the furrow slice of 10-in depth was completely inverted, a layer of slowly permeable subsoil formed the soil surface. This condition is extremely bad from a water-control or crop-production standpoint. It appeared desirable, therefore, to stand this thick furrow slice on edge as closely as practical. In this way, some organic matter would be placed as deep as 10 in and some subsoil would be moved to the surface. These studies are not yet of sufficient duration to provide any conclusions.

CONCLUSIONS

Moisture in the soil-pore reservoir within the root zone in the summer season is usually quite low and the volume of unfilled pores large enough to take up several inches of rainfall. Observations on clean-tilled land indicate that runoff and erosion have resulted from summer storms when there was within the 7-in topsoil enough pore space to take up the entire amount of the storm rainfall. Studies show that the sealing of the soil surface, which limits the rate of water intake into the soil, can be mostly eliminated by the use of mulches. Water absorption into mulched cornland soil was maintained at high rates while such rates rapidly diminished under normal farming practices.

Mulch culture for corn or other clean-tilled cropland appears to offer a practical aid in solving the problem of beginning the soil- and water-conservation program at the point where the raindrop falls. Different soils and moisture conditions require variations in the manner of getting a mulch and timing (early, middle, or late season) of the application of mulches. Many phases of land operations under mulch culture are yet unanswered, and there is a great need for expanded study and coordination of research efforts. The time is rapidly approaching for mulch culture to take its place as another great contribution to the science of soil and water conservation.

The use of mulches and other conservation practices which tend to make more effective use of soil porosity immediately beneath the soil surface are just part of the problem. Further reductions in soil and water losses of significant amounts may be found possible as a result of studies of methods for improving the permeability of the soil profile within the root zone. When the restriction of a sealed soil surface is wholly or partly removed, then provisions need to be made for rapid transmission of the infiltrated water to lower horizons. Where highly permeable topsoils are of shallow depth and are underlain by soils of much less permeability, the use of much of the soil reservoir for water conservation is greatly restricted. Studies are therefore being conducted to increase the effective depth of topsoil by subsoiling, deep applications of lime and fertilizer, and deeper plowing. These studies are not yet conclusive.

It is the purpose of this paper to illustrate the value of land operations designed to improve the use of soil porosity for greater water conservation. Much more needs to be done along the lines of research and field trial before the soil reservoir of many soil types is used to the best advantage.

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(Continued on page 292)

Dairy Cattle Loafing Barns Designed for Summer Temperature Control

By G. L. Nelson and E. R. Berousek
MEMBER ASAE

ANIMAL physiologists have shown that dairy cows usually have difficulty in becoming adjusted to hot summer weather, and that prolonged periods of environmental temperatures above 75 to 85 F generally result in decreased milk production (2) (5)*. Many states in the central and southwestern regions of the United States have long periods of hot summer weather when daytime temperatures are above 85 F. Fig. 1, based on five-year records of the U.S. Weather Bureau (1), shows the total number of hours of dry-bulb temperatures above 85 F that occur annually in the United States. Texas, Louisiana, Arkansas, Oklahoma, Kansas, Missouri, and Mississippi — all lying wholly or partially within the 750-hr zone — have 20 per cent of the dairy cattle population of the United States, but produce only about 11 per cent of the nation's milk supply. Dairymen in these hot-weather areas need to know to what extent they can overcome depressing effects of hot weather by providing cool shelter for dairy cattle without departing from established herd-management and summer-pasturing practices. Farm-buildings specialists need to know how shelters for dairy cows can be made more comfortable during hot weather. The Oklahoma Agricultural Experiment Station started experiments at Stillwater in the summer of 1950 to obtain data on the performance of a temperature-controlled and an uncontrolled shelter for dairy cattle, and the comparative effects of these shelters on dairy-herd performance during hot weather. The first summer's work gave little evidence as to effects on dairy cattle. Data were obtained on performance of the shelters which, together with the design of the shelters, is of interest.

The two dairy-cattle shelters which have been built for the experiments are shown in Figs. 2 and 3, respectively. The temperature-controlled shelter (Fig. 2) is a completely enclosed structure, 26 ft wide by 50 ft long, with an entrance vestibule and instrument room on the east end. Lightweight concrete block manufactured with an expanded shale aggregate, and with core spaces filled with the same kind of aggregate to reduce heat gain, were used for wall construction. The south wall and windows are shaded by the roof overhang to help reduce heat gain due to sun effects. The shelter is ceiled with cement-asbestos sheathing on the lower chord of the trussed rafters and roofed with corrugated aluminum on 2 × 4-in purlins. Cooling and ventilating equipment for temperature control includes an 8000-cfm evaporative cooler, which discharges into the west end of the shelter, and two 30-in attic fans. Cooler operation is controlled by a switch which responds to a five-degree temperature variation.

The west-facing and south-facing walls incorporate special concrete masonry wall panels built from three different kinds of concrete block and with three different kinds of core filling. These panels were used to obtain data on exterior and interior wall-surface temperatures as affected by the kind of masonry wall construction.

The other shelter, shown in Fig. 3, is an open-front, south-facing loafing barn, 26 ft 6 in wide by 48 ft 8 in long. The roof is covered with corrugated aluminum, but the shelter space is not ceiled. The north wall consists of 4 × 4-ft plywood panels which can be removed to provide any desired pattern of rear-wall ventilation openings.

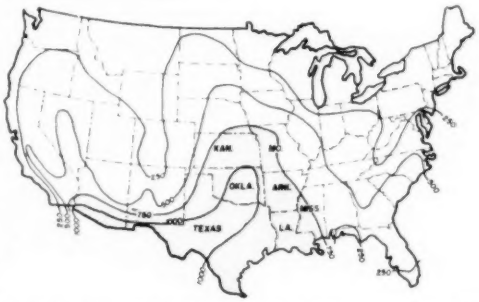

Fig. 1. Average annual number of hours of temperatures above 85 F occurring in the United States.

The site for the experimental shelters is on a south slope that is unshaded and well exposed to prevailing southerly winds. Each shelter is in a separate pasture of approximately 15 acres varying in grazing quality from poor to good. Both pastures are comparable in size and carrying capacity.

The dairy cattle used in the experiments in the summer of 1950 consisted of two ten-cow groups. Each cow in one group was paired with a cow of the same breed, comparable history, and physical characteristics in the other group. The groups were alternated on a ten-day, double-reversal cycle between the two pastures. Each group had free access at all times to the shelter in the pasture which the herd was using.

Temperatures and Other Conditions in the Temperature-Controlled Shelter. A continuous trace of dry-bulb tempera-

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*Numbers in parentheses refer to the appended references.

Fig. 2. Temperature-controlled, experimental dairy-cattle shelter used for summertime experiments at the Oklahoma Agricultural Experiment Station. (Photo courtesy Kaiser Aluminum Co.)

Fig. 3. Open-front experimental dairy-cattle shelter used for summer-time experiments at the Oklahoma Agricultural Experiment Station. (Photo courtesy of Kaiser Aluminum Co.)

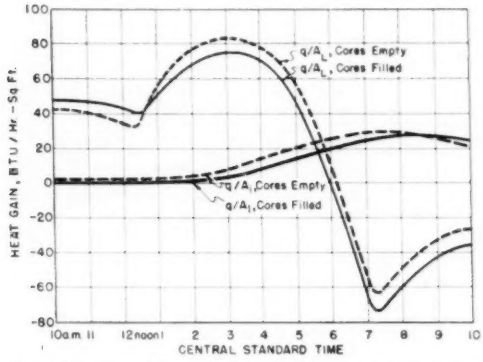

Fig. 4. Summertime heat gain characteristics for 8-in. sand and gravel aggregate concrete block in a west-facing wall at Stillwater, Okla.

ture and relative humidity existing in the temperature-controlled shelter was obtained with a circular-chart recorder mounted 5 ft above the floor on a steel column in the shelter space and protected by a steel cage from damage by the cows. The maximum dry-bulb temperature in the shelter during the hottest weather was 84 F. Temperatures during seven of the hottest days during the experimental period averaged 80 F during the hottest hours of the day. Outdoor-indoor temperature difference averaged 11 F during the hottest part of the day. Relative humidity averaged about 80 per cent in the shelter, except after prolonged operation of the evaporative cooler when relative humidity would rise to about 90 per cent.

Heat Gain Through Concrete Masonry Walls. Indoor and outdoor surface temperature observations were made on six special concrete masonry wall panels in the west-facing wall of the shelter. Each panel is 4 ft high by 2 ft 8 in wide. The materials used in the six panels included concrete block made with sand and gravel aggregate, concrete block made with lightweight expanded shale aggregate, and concrete block made with lightweight pumice aggregate. One panel of each kind of block was built with the cores empty, and one with the cores filled with lightweight aggregate. Two thermocouple junctions were installed in each face of each panel. Half hourly readings of indoor and outdoor surface temperatures at these thermocouples were made between the hours of 9 a.m. and 12:00 noon and between 1:00 p.m. and 6:00 p.m.

Based on these surface-temperature data and pyrheliometer traces of solar-radiation intensities, heat gain rates to the outdoor surface and to the indoor air were computed using selected surface coefficients of conductance and solar absorptivity. These results for seven of the hottest days occurring in the 1950 summer experimental period are shown in Fig. 4 for sand-and-gravel-aggregate concrete block. Heat gain to the outdoor surface is denoted as q/A_1 and indoor air as q/A_i. The core filling was pumice aggregate. It is evident that considerable reduction in heat gain to indoors during the afternoon hours is achieved by filling the core spaces. Fig. 4 also clearly shows the time lag and periodic nature of summertime heat gain through walls exposed to solar radiation.

Those who are interested in estimating heat gain during periodic heat flow through concrete masonry walls of temperature-controlled animal shelters need a method to which local outdoor temperature and solar-radiation-intensity data can be applied. The ASHVE Guide (4) outlines a method for computing heat gain under summertime conditions of periodic heat flow for different kinds of wall construction based on an analysis that involves the density, specific heat, thermal conductivity, thermal lag and heat-gain decrement under periodic heat flow, the thickness of the wall, and the character of the wall material.

The concept of an "apparent" over-all heat transfer coefficient, U_e, might be used for a more direct method of estimating heat gain under periodic heat flow. Fig. 5 shows some values of U_e for sand-and-gravel-aggregate concrete block in a west-facing wall. These values were computed from the heat gain data of Fig. 4 for q/A_i by applying the expression

$$U_e = \frac{q/A_i}{t_e - t_i}$$

where U_e = "apparent" over-all heat transfer coefficient for periodic heat flow, Btu per hr · sq ft · F temperature difference, sol-air temperature minus indoor air temperature

q/A_i = instantaneous heat gain rate from indoor wall surface to indoor air, Btu per hr · sq ft, computed from measured temperature differences

t_e = sol-air temperature, deg F, computed from measured solar and sky radiation intensities and outdoor temperatures

t_i = constant dry-bulb temperature of indoor air, F.

In order to use the graph, data would be needed on sol-air temperatures throughout the day. The sol-air temperature is a computed temperature, which in the absence of solar and sky radiation would give the same rate of heat entry to the outdoor wall surface as actually occurs with the existing combination of solar and sky radiation and outdoor air temperature. Sol-air temperature is defined by

$$t_e = (b/f_o) I_t + t_o$$

where b = absorptivity of wall surface for solar and sky radiation, dimensionless

f_o = outdoor surface film coefficient, Btu per hr · sq ft · F temperature difference

I_t = intensity of solar plus sky radiation incident on the wall, Btu per hr · sq ft

t_o = outdoor air dry-bulb temperature, F.

If sol-air temperatures are known, instantaneous heat gain to indoors at each hour could be computed by $q/A_i = U_e (t_e - t_i)$, where U_e is selected from Fig. 5. Obviously the values for U_e shown in Fig. 5 would not be suitable for walls with other orientations or in areas where the pattern of sol-air temperature variation is not comparable to that in central Oklahoma. However, similar data could be developed to meet other conditions.

Attic-Space Temperatures. A method for predicting attic-space temperatures over cooled shelters is necessary before one can estimate heat gain to cooled space below. Under given weather conditions, the temperature in an attic space will be influenced by the kind of materials used for roof and ceiling construction, ventilation of the attic space, and temperature below the attic space. The attic space in the temperature-controlled shelter was ventilated with a louvered opening in the east gable end with a net free area of 11½ sq ft, and an access door with an opening area of 7½ sq ft in the west gable end. Temperatures at a thermocouple junction suspended near the middle of the attic space were observed at half hourly intervals.

By writing a heat balance for the attic space in the temperature-controlled shelter, it can be shown that, for rates of

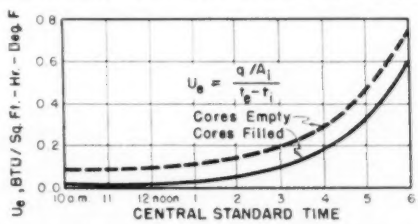

Fig. 5. Graph of U_e versus CST for 8-in. sand and gravel-aggregate concrete block in a west-facing wall at Stillwater, Okla.

air movement in the order of 1¼ mph through the attic space, the attic temperature, t_a, will be a function of the sum of the outdoor air temperature, t_o, and the mean, t_{eq}, of the sol-air temperatures of the two slopes of the roof. A graph of the ratio $t_a/(t_{eq} + t_o)$ is shown in Fig. 6. This dimensionless ratio is based on measured attic temperatures, outdoor air temperatures, and solar-radiation intensities. All values of this ratio fall between 0.42 and 0.50 during the hours 10:00 a.m. to 6:00 p.m. For estimating temperatures in attic spaces comparable to the one in the temperature-controlled shelter, an intermediate value of about 0.45 might be used. This ratio could be used to estimate attic temperatures if data are at hand for first computing sol-air temperatures for the roof covering.

Air Motion Through Open-Front Shelters. Livestock specialists are of the opinion that open shelters are more comfortable for cattle during hot weather, if the shelter is designed to allow generous amounts of air to sweep through the shelter. It is known that air velocity affects the coefficient h_c of forced convection heat transfer between a surface and the surrounding air. For atmospheric air at 70 F flowing over smooth, plane surfaces at velocities less than 15 fps, King and Knaus (3) recommend the formula

$$h_c = 0.8 + V/16{,}400$$

where h_c = coefficient of forced convection heat transfer, Btu per hr - sq ft - deg F

V = air velocity, ft per hr.

They state that this coefficient may be increased as much as 50 per cent if the surfaces are very rough. If the hair texture and body conformation of a dairy cow is such that this formula is appropriate with a roughness correction factor of 1.25, the expression obtained for the coefficient for a cow's surface is $h_c = 1 + 0.404\,V'$, where V' is air velocity expressed in miles per hour. Applying this expression to forced convection cooling of a cow with a 5-mph wind and a body area of 50 sq ft, a convection cooling effect of 780 Btu per hr is computed with the cow's surface 5 deg warmer than the ambient air. Cooling effect of this magnitude could be important inasmuch as the total heat production of a lactating dairy cow is in the order of 5,000 Btu per hr. If the air velocity is decreased to 1 mph, the computed cooling effect is about 350 Btu per hr. Therefore, with a favorable temperature difference, it is reasonable to expect benefit if dairy-cattle shelters with open fronts are designed to obtain increased air motion through the shelter when breezes occur. The question then arises concerning the effect of different amounts and patterns of rear-wall openings on air motion through open-front shelters.

Data were collected on velocity of air motion through the open-front shelter with panels removed from the lower row in the rear or north wall of the shelter. The method consisted of making anemometer traverses along a horizontal rail at heights of 2 ft 6 in and 5 ft 0 in, respectively, above the floor of the shelter. Two traverses were made at each height, one along a line 6 ft from the front of the shelter and another along a line 6 ft from the rear wall of shelter. Before and after each 12 ft bay of the shelter was traversed, an outdoor wind velocity reading was made 4 ft above ground on an outdoor stand. All observations were made during southerly winds

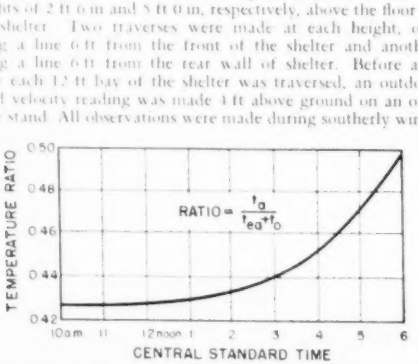

Fig. 6. Graph of attic space temperature ratio for the temperature-controlled dairy-cattle shelter.

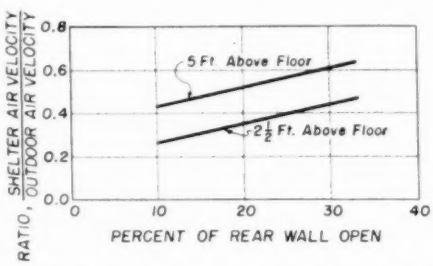

Fig. 7. Effect of rear wall openings on air motion through the open-front, south-facing, dairy-cattle shelter.

and with the anemometer oriented to face south. The results of these experiments are shown in Fig. 7. Fig. 7 is applicable to the center section of the shelter only, because end-wall effects caused considerable reduction in air motion within the 12-ft space adjacent to each end wall. The "Per Cent of Rear Wall Open" in Fig. 7 is equivalent to 100 times the quotient of the area opened by removal of panels from the lower 4½ ft of rear wall divided by the total rear-wall area measured from floor to top of wall plate. Additional permanent openings due to spaces between the rafters over the rear-wall plate and spaces between the 2 x 4-in roof-covering nailers over the gable end walls amount to about 1 per cent of the total rear-wall area.

Performance of the Dairy Herds. The two matched groups of dairy cows were alternated on a ten-day, double-reversal cycle between the two pastures and allowed free access to the shelter in each pasture. Milk production records for the two herds showed no effect from access to the cool shelter. It is important to note that the cows in either herd spent an average of less than one-half hour per day in either shelter and that the summer was unusually cool, with maximum outdoor temperature of 97 F during the experimental period. It is not reasonable to expect that this low amount of occupancy of the shelters would cause differences in milk production to occur. It was observed that the cows seemed to be governed by habit and preferred to seek the shade of large trees at a considerable distance from the shelter rather than remain in the cool shelter, even during hottest weather of the experimental period. It is possible that dairy cows need to be trained to overcome habits which cause them to seek natural shade or remain outdoors rather than use cooled shelters.

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(Continued from page 289)

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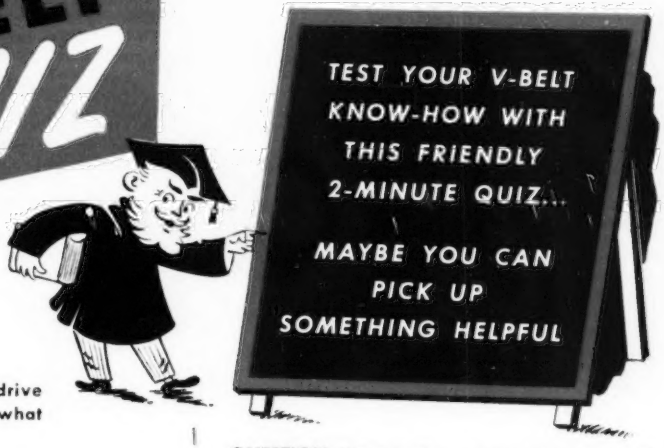

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Terraces on Grassland

By Maurice B. Cox, H. A. Daniel and H. M. Elwell
MEMBER ASAE

THE question of whether terraces are needed on grassland is often discussed. Until recently, however, no research data were available. This report is based on a study of two areas of shallow, eroded, abandoned Class VII land where a cover of native grass had been re-established on the Red Plains Conservation Experiment Station, Guthrie, Okla.[1] One plot had been terraced before it was returned to grass. The other was unterraced.

This study shows that on this type of grassland these terraces caused greater runoff to occur. After the grass cover became established, the percentage of runoff was greater on the terraced plot than on the unterraced one. Grass cover was considerably better on the unterraced plot than it was on the one that has been terraced. Forage yield in 1950, the eighth year after grass was established, was more than three times as great on the unterraced plot.

The results obtained in this study, it is believed, will apply on similar types of land throughout the Cross Timbers and Reddish Prairies of Oklahoma, and probably in other areas having similar soils and limited summer rainfall.

HOW THE STUDY WAS MADE

The Soil. This study was made on Class VII land typical of much of the shallow, eroded, abandoned land in the Southwest. The plots are on reddish prairie soil which is shallow, medium textured and slowly permeable.[2] When the experiment began they were severely eroded and a compact subsoil was exposed. Approximately 11 in of topsoil had been removed during 40 years of continuous cultivation.[3]

The Plots. The two areas used for a study of the effects of terracing were established in 1929. They were laid out so as to be as nearly alike as possible in soil condition, size, natural slope and other characteristics. Terraces were built on one of the areas and the other was left unterraced. Devices to measure water runoff and soil losses were set up for each area. Rainfall was measured by recording gage.

The unterraced area measured 3.21 acres and had an average slope of 5.13 per cent. The terraced area was 3.13 acres and it had a natural land slope of 3.42 per cent. Four large level, ridge-type terraces were built at vertical intervals of 2.5 ft. They occupied about one-third of the total land surface and markedly increased the average land slope. The back slopes of the terrace ridges were quite steep. One end of each terrace ended in the dike separating the experimental watersheds. The other end emptied into a channel, and the runoff water was measured at the outlet of the lower terrace.

Management of the Plots. The two plots were cultivated alike from 1930 through 1938, using a rotation of cotton and cowpeas. Yields were poor[3] because this Class VII land is not suitable for cultivation. It is very droughty and low in plant nutrients. Therefore in the spring of 1939 both areas were seeded to a mixture of native grasses.

WHAT THE STUDY SHOWED

About Runoff. During the period of cultivation, both runoff and soil losses were much greater on the unterraced land.[4] Average annual runoff was 7.11 in from the unterraced plot and 4.10 in from the terraced plot. Annual soil loss averaged 83.72 tons per acre from the unterraced plot and only 4.43 tons from the plot that was terraced.

The foregoing figures show that terraces were effective in preventing soil from leaving the field while the land was being cultivated even though much washing occurred between terraces. But after the land was regrassed the story was different. The changes are shown in Fig. 1.

While the grass was becoming established, the terraces continued to reduce runoff water losses. But, as the grass cover improved, the terraces became less valuable. The fourth year after grass was seeded the amount of runoff from the two plots was practically the same and the fifth year it was higher from the terraced land. Since that time, runoff conditions have been almost exactly the reverse of what they were while the land was being cultivated. In fact, the percentage of runoff from the terraced land in grass has been slightly higher than it was from the unterraced plot during cultivation.

The relatively greater runoff from the terraced land after regrassing probably can be explained as follows:

Building and maintaining the terraces on this shallow, severely eroded land moved most of the small remaining amount of permeable topsoil into the ridges, and at the same time exposed more of the compact unweathered subsoil in the channels and terrace intervals. This subsoil layer does not take water readily (Fig. 2).[4] Therefore, the rainfall not absorbed immediately by the soil on the ridges accumulated rapidly in the channels and was quickly drained off the land. Rapid runoff also was favored by two other conditions existing on the terraced area but not on *(Continued on page 296)*

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Houston, Tex., June, 1951, as a contribution of the Soil and Water Division.

The authors MAURICE B. COX, agricultural engineer; H. A. DANIEL, project supervisor, and H. M. ELWELL, soil conservationist, Red Plains Conservation Experiment Station (Guthrie, Okla.), Soil Conservation Service, U. S. Department of Agriculture.

[1]Operated jointly by the U.S. Soil Conservation Service and the Oklahoma Agricultural Experiment Station.

[2]Soils classified as Chickasha and Zaneis (shallow phases).

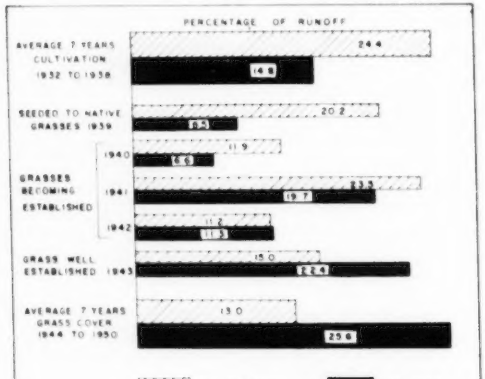

Fig. 1. Runoff from terraced and unterraced land while in cultivation and after re-establishment of grass. While the land was cultivated (cotton and cowpeas), terraces were effective in reducing runoff. But after the land was regrassed, conditions were almost exactly reversed and runoff was greater from the terraced area.

[3]A more complete description of the soil is given in USDA Technical Bulletin 837 (1944), "Investigations in Erosion Control and Reclamation of Eroded Land at the Red Plains Conservation Experiment Station, Guthrie, Okla., 1930-40," by H. A. Daniel, H. M. Elwell and Maurice B. Cox.

[4]The measurements reported in Fig. 2 were made by inserting 5-gal bottles filled with water into holes dug into the soil. The bottles were supported by metal rims of 8-in diameter set into the upper part of the holes that extended 7 in below the necks of the bottles. Absorption rates were recorded by measuring the drop in the water level in the bottles.

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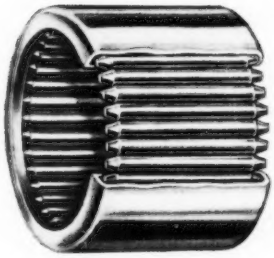

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Terraces on Grassland

(Continued from page 294)

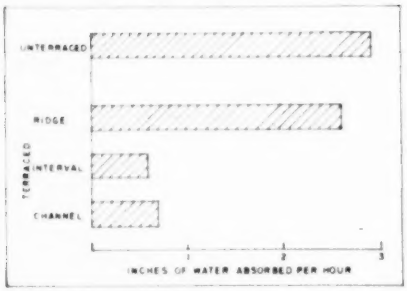

Fig. 2. Rates of water absorption on terraced and unterraced land. These figures help explain why runoff was higher from the terraced land after it was regrassed. The ridges took moisture almost as well as the unterraced soil, but, where a tight subsoil had been scraped bare in making the ridges, rainfall did not penetrate easily. (These data present only an indication of water absorption, and not true infiltration rates[4].)

the unterraced plot. First, the runoff water had a shorter distance to travel before it accumulated into channel-flow conditions. This gave it less time to soak in. Second, the terraces greatly increased the original land slope; therefore, the water from the ridges not only had a shorter distance to travel but also moved over the surface more rapidly.

About Grass Production. The mixture of native grasses planted on the two experimental areas included both short and tall types: blue grama, buffalo, dropseed, little bluestem, big bluestem, switch and Indian grasses. An excellent stand developed on the unterraced land, including previously gullied portions. Little bluestem and blue grama predominated everywhere except in the channels and on the ridges of the terraced plot.[5] In the channels, upland switch grass made up the greatest percentage of the cover, and on the ridges plant growth was largely weeds and early annual grasses. In the channels, switch and Indian grasses grew best. They made considerable root development in some channels, but apparently did not penetrate the soil enough to influence water absorption.

In 1950 the unterraced land produced $3\frac{1}{4}$ times as much hay as the terraced land. Rainfall was above the average all during the growing season for grass that year. Observations made on these plots in previous seasons, and on adjacent terraced pastures on Class IV land, agreed with the measured results obtained on the experimental plots in 1950.

The poor yield from the terrace ridges probably was due to soil moisture conditions, as shown by Fig. 3. Other studies show that terrace ridges often become very dry and produce poor yields of cultivated crops, and the same condition apparently affects grass. The exposed subsoil between the terraces allowed heavy runoff and failed to produce good grass.

CONCLUSIONS

Soil conditions are important factors to consider in making conservation farm plans. Shallow, sloping, highly erodible Class VII land is more stable and useful when put to permanent vegetation. In regrassing gullied land, special treatment may be necessary. The first step will be to reduce further erosion and stabilize the seedbed. In some areas it may be necessary to divert the runoff water from the original channels by small diversion terraces above the heads of the gullies since the oversized terraces used on the experimental tract were not desirable. Another part of this process is the installation of vegetative barriers of brush and crop residues, and plowing and grading down the gully banks. The seedbed is ready for fertilizer and lime as needed and the planting of legumes.

[5]Percentages by species and location are given in Table VII of Okla. Agricultural Experiment Station Bulletin B-25, "Conservation and Better Land Use for Oklahoma," by H. A. Daniel, H. M. Elwell and H. F. Murphy.

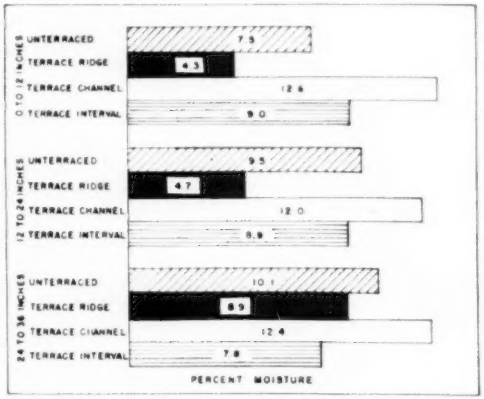

Fig. 3. Percentage of moisture at different depths on terraced and unterraced land. Moisture samples were taken in the fall of 1950, after a summer that was the wettest on record. This was 11 years after the grass was seeded. The dry ridge was supporting a very sparse stand of grass. The unterraced land had an excellent cover of tall native grasses, which possibly may account for the low moisture content in the first foot layer of soil on this area.

Following the establishment of legumes, grasses may be seeded by the seed hay method.

The results obtained show that large oversized terraces were actually detrimental to grass production and water conservation on the shallow eroded Class VII land used in this experiment.

RECORDING CONCENTRIC RING INFILTROMETER

Infiltration of water into the soil with concentric-ring infiltrometers has been studied by scientists since the 19th century. Until recently, however, the rate of water entering the soil was obtained by recording both the time and amount of water drawn from a calibrated bottle. This picture shows a rain gage recording the intake of water into the soil. It was developed by Maurice B. Cox, agricultural engineer of the U. S. Soil Conservation Service, cooperating with Oklahoma A. & M. College at the Red Plains Conservation Experiment Station, Guthrie, Okla. The instrument consists of the concentric rings, two carburetor floats, ten-gallon oil drum, and the recording rain gage. The inner ring was made 8 in. in diameter in order to correspond with the calibration of the rain gage. By making it the same size as the top of the gage, the water entering the soil was recorded correctly on the rain gage chart. Water for the outer ring was supplied by gravity from the drum. The water for the inner ring was siphoned from the previously filled bucket inside the rain gage. The water level in the two rings was maintained uniform and constant by carburetor floats. Accurate rates of infiltration were obtained for periods of time as great as 60 hr. A distinct advantage of this equipment is the use of the rain gage for the recording instrument. No altering of the gage is necessary.

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The Physiological Aspects of Chick Brooding

By James H. Bywaters

PHYSIOLOGICAL aspects of chick brooding involve a study of the characteristics of or appropriate to the chick's healthy functioning. These characteristics are basically heredity and environment. Heredity furnishes the fundamental spark of life and the potential framework, organization and function of the body while environment furnishes the necessary building materials and stimuli.

Thus if we knew the absolute optimum environmental needs of each chick and could furnish that environment from moment to moment to each chick, then each member of our flock would live, grow, feather, reproduce, and die in keeping with its individual genetic potential.

This obviously is highly improbable, but it is equally obvious that all our concern with nutrition, management, housing, brooding, incubation and disease control are aimed at this goal. The closer, within limits, we approach this goal, the more efficient will be our poultry production, provided the birds with which we work are genetically satisfactory.

The poultry breeder is constantly endeavoring to improve the hereditary worth of his chickens while everyone else is trying to improve the environment, and neither group can solve the many problems alone. Books have been written summarizing the available information on poultry breeding, management, brooding, incubation, nutrition and disease control. Literally hundreds of articles have been written on the physiology of individual parts of the chicken. Considerable information is available on the physiology of reproduction and on the physiology of the hen. There is a tremendous volume of practical suggestions, recommendations and directions for brooding chicks, but there appears to have been little done on the actual physiology of the chick during that period.

For this limited discussion it will be necessary to assume adequate feeding and that the chicks are normal (whatever that means) and healthy.

We know, of course, that the chicken is a warm-blooded animal in which most of the embryological development takes place outside the maternal body. During this external incubation period the embryo is aquatic and surrounded by an ambient temperature of approximately 99 F and a relative humidity of about 60 per cent.

At hatching, the temperature is reduced to 96 to 98 F and the humidity raised to 75 to 78 per cent. From this hot humid environment the chick is transferred to a hot but relatively dry environment in a house that is constructed, not in accordance with his needs but in keeping with the needs of his master. Hill (1951) comments: "... if human dwellings were built along similar lines ceilings would be from 40 to 50 ft in height!"

The most comprehensive work on the general physiology of the baby chick we know of is that of H. G. Barott and Emma M. Pringle (1946-47-49a, 50) in a series of experiments at the U. S. Department of Agriculture's Agricultural Research Center at Beltsville, Md.

Metabolism and Temperature. They found that the metabolic rate for all ages of chickens from hatch to maturity at various temperatures is highest at 8 a.m. and gradually declines to a low at 8 p.m. Furthermore, the metabolic activity per gram weight of chicken per hour is greater for baby chicks and progressively decreases as the chicks get older.

However, the total metabolism (the value in units per hour per gram weight of chicken times the weight of the chicken) is the lowest for the baby chick and increases rapidly as the chicken's weight increases from 40 to 300 g. The rate of increase then gradually decreases as the weight of the bird increases until it is practically zero at weights over 2800 g. These data were obtained from Rhode Island Red females, and one would expect the changes in metabolic rates to occur at somewhat different weights for the males.

These authors also found that for each age there was a temperature at which metabolism was a minimum. This temperature was found to be 94-95 F for day-old chicks and decreased about 0.8 F per day through the 32nd day. At one year of age, this optimum temperature was found to be 70 F.

At temperatures below these optimum temperatures, the chicks need more heat and this is supplied by increased metabolic activity. This increase continues until the chicks are no longer able to produce enough heat to maintain body temperature and they die from cold. Thus chicks from a day old to two weeks of age are unable to survive a temperature below 70 F for twenty-four hours, chicks five and eight weeks of age under a similar exposure die at temperatures below 50 F. Similar lethal temperatures have not been determined beyond eight weeks of age.

Metabolic activity also increases when the ambient temperature rises above the optimum temperature. This is primarily due to the extra effort required in panting to evaporate extra moisture from the respiratory tract for cooling purposes to maintain the body temperature. This process too has a limit beyond which the bird cannot go and it dies from the heat. Thus the exposure of a baby chick to a temperature of about 104 F for twenty-four hours is lethal while a similar exposure of a mature pullet at 90 F is disastrous.

It can be seen from these data that a chick's thermoregulatory system can cope more readily with deficient temperatures than it can with excessive heat.

Temperature and Feed Efficiency. In these same series of experiments, the authors found that chicks raised under the descending temperatures at which the metabolic activity was the lowest were more efficient in converting feed into body weight. Both growth and feed efficiency became less as the temperature was varied in either direction from this optimum. These effects decreased, however, as the birds got older.

Heat and Respiratory Water Elimination. The respiratory quotient and the carbon dioxide and oxygen thermal quotients were computed from the observed data for the period from 8 a.m. to 8 p.m. There appeared to be very little variation in the RQ of 0.717 with either temperature (except for a slight decrease below 40 F) or age of the chick. The oxygen TQ was 3.11 and the carbon dioxide TQ was 3.16 and neither appeared to be affected by the temperature or the age of the bird.

The heat elimination of chicks in calories per hour per gram of live weight at the approximate temperature at which minimum metabolism occurs was found to be (Modified after Barott and Pringle, 1946):

Temperature	Age (weeks)	Weight in grams	Calories
95	0.4	36	5.50
85	2	90	7.85
70	5	260	8.15
70	8	590	5.85
70	12	1030	4.25

At temperatures below that at which minimum metabolism occurred, the water of respiration in milligrams per hour per gram of live weight was quite constant with respect to temperature but decreased from about 1.60 for day-old chicks to about 1.15 for 12-weeks-old chicks. During the 30-day period covered in their 1950 paper, these authors estimated that their birds consumed about 1.75 g of water for each gram of feed eaten.

The humidity of the environment in these experiments appeared to have no effect on growth to eighteen days.

(Continued on page 312)

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., 1951, as a contribution of the Rural Electric Division.

The author: JAMES H. BYWATERS, research professor of poultry husbandry, Virginia Agricultural Experiment Station, Blacksburg.

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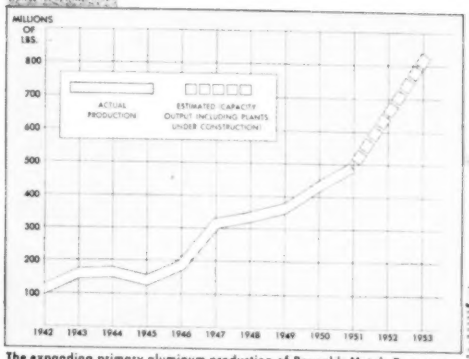

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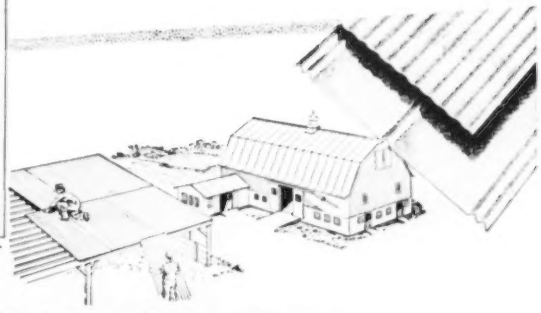

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NEWS SECTION

ASAE Annual Meeting Program

THE program for the 45th annual meeting of the American Society of Agricultural Engineers to be held at Kansas City, Mo., June 16-18, has been completed, and copies have been mailed to members of the Society. Copies will be gladly mailed also to non members of the Society interested, on request to the Society office at St. Joseph, Michigan.

The program for this meeting has been carefully arranged and will appeal strongly to all agricultural engineers. The forenoons of each of the three days will be given over to concurrent programs of the Society's four technical divisions — Power and Machinery, Rural Electric, Farm Structures, and Soil and Water. The first general program of the meeting will be presented the afternoon of June 16 and will include the annual address of ASAE President Stanley Mahill, executive engineer, John Deere Waterloo Works of Deere Mfg. Co., and an address by Henry Dreyfuss, the noted industrial designer. This will be followed by the annual business session of the Society. Special programs of the College Division, the Committee on Extension, and other groups will be held during the evening of the same day. Also, the Committee on Extension is again arranging for the extensive educational exhibits such as the committee has sponsored at this meeting in recent years.

The afternoon and early evening of the second day, June 17, will be devoted to a trip to a most unusual farm near Kansas City which will be of particular interest to agricultural engineers, and inspection of the farm plant will be followed by a chuck wagon dinner made colorful by western atmosphere.

The second general session of the meeting will be held on Wednesday afternoon, June 18, the program for which is being arranged by the College Division of the Society. The program of this session will open with a discussion on how college research helps industry to serve agriculture, the speakers on this subject being D. G. Womelsdorff, Public Service Co. of Northern Illinois, and R. M. Merrill, Deere & Co. This will be followed by a talk by C. J. Scranton, Allis-Chalmers Mfg. Co., on the subject "The Graduate Engineer and Farm Equipment Design." Following this, L. H. Skromme, New Holland Machine Div., The Sperry Corp., will talk on the language of the design engineer.

The usual high point of each ASAE annual meeting will be the Society's annual dinner to be held as the closing event of the meeting on Wednesday evening, June 18. The dinner will be followed by dancing.

A special program is also being arranged for members of Student Branches of ASAE who will be in attendance at the meeting. The high point of this program will be the complimentary dinner given to the attending students by the International Harvester Co.

The subjects and speakers to be featured on the programs being arranged by the four technical divisions are as follows:

POWER AND MACHINERY PROGRAM

Recent developments in the mechanization of peanut crop production will be the principal topic for the session of the forenoon of June 16, with Gertice B. Hill, division chairman, presiding. Norman C. Teter, North Carolina State College, will discuss the subject from the standpoint of the North Carolina-Virginia area, Fred A. Kummer, Alabama Polytechnic Institute, will talk on developments in the Alabama-Georgia area, and the progress in mechanization in the Texas area will be discussed by J. W. Sorenson, A. & M. College of Texas. The final number of this session is a progress report on standardization of taillights for farm equipment by Martin Rominne, Minneapolis-Moline Co.

The forenoon session on June 17, with R. I. Wortell, vice-chairman of the Division, presiding, will include four numbers. A joint paper by L. G. McKibben, I. F. Reed, and C. A. Reaves, USDA Tillage Machinery Laboratory, will present results of research on the effects of rim widths on tractor tire performance under four conditions. Some of the engineering developments and challenges in chemical weed control will be subject of a talk by E. D. Anderson, National Sprayer and Duster Assn., which will be followed by a presentation by O. B. Wooten, Jr., U. S. Department of Agriculture, discussing developments in directional spray equipment for weed control in Southern crops. The story of the engineering development of the new International Harvester sugar cane harvester will be presented by J. E. Hipple of that company.

The program on the forenoon of June 18, with George B. Hill, division chairman, presiding, will feature the subject of castor beans. The program will open with a paper by D. L. Van Horn, agronomist at the Oklahoma Agricultural Experiment Station on the production and uses of castor beans which will be followed by M. E. Arms, University of Nebraska, in a discussion of the development of a special machine for harvesting castor beans on which he has worked. Harvesting castor beans by the combine method will be discussed by H. C. Smith, Massey-Harris Co. A joint paper by E. W. Schroeder, Oklahoma A. & M. College, and I. F. Reed, U. S. Department of Agriculture, will go into the development and performance of tractor-mounted castor bean harvesters. I. G. Schoenleber and W. M. Hurst, U. S. Department of Agriculture, will talk on the performance of castor bean hulling plants, and the session will close with a report of test results on an experimental castor bean huller by I. G. Porterfield and F. J. Oppel, Jr., Oklahoma A. & M. College.

RURAL ELECTRIC PROGRAM

With H. S. Hinrichs, chairman, Rural Electric Division, presiding, the Rural Electric program on June 16 will open with a talk by F. C. Lathrop, USDA Northern Regional Research Laboratory, discussing the processing of agricultural residues. The second paper on the program deals with heat and energy requirements for drying small grains and will be presented by H. J. Barre of Purdue University. The third and last number on the program of this session will be presented by A. S. Mowery, Pennsylvania State College, who will discuss the vertical elevator for handling chopped forage.

The Rural Electric Division and the Farm Structures Division are sponsoring a program jointly on the forenoon of June 17. The program will open with a paper on recent developments in the pipeline milker and bulk handling of milk by S. A. Witzel, University of Wisconsin. This will be followed by a paper on an automatic milker for the small operator by W. H. Harstick, International Harvester Co. W. M. Hurst, U. S. Department of Agriculture, will talk on the subject of farm and small commercial poultry dressing plant layout and operations.

FARM STRUCTURES PROGRAM

The forenoon session of June 16, with C. K. Otis, chairman, Farm Structures Division, presiding, will open with a report of research on physical properties of structural panels made (Continued on page 502)

ASAE Meetings Calendar

May 16 and 17—ALABAMA SECTION, Gulf Breeze Inn, Gulf Shores, Ala.

June 16-18—45TH ANNUAL MEETING, Hotel Muehlebach, Kansas City, Mo.

August 25-27 — NORTH ATLANTIC SECTION, University of Maine campus, Orono.

September 8 and 9—ASAE PROGRAM, Centennial of Engineering Convocation, LaSalle Hotel, Chicago, Ill.

October 30-November 1 — PACIFIC NORTHWEST SECTION, Oregon State College, Corvallis.

December 15-17—WINTER MEETING, Edgewater Beach Hotel, Chicago, Ill.

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Michigan.

THE NEW 1952-53 OFFICERS OF THE VIRGINIA SECTION

In this picture are shown four of the five new officers of the Virginia Section of the American Society of Agricultural Engineers installed at the business session of the Section's annual meeting held at Natural Bridge, Va., April 4 and 5. Left to right: James H. Lillard (vice-chairman), associate agricultural engineer, Virginia Agricultural Experiment Station; J. Lawrence Calhoun (chairman), associate extension agricultural engineer, Virginia Polytechnic Institute; I. E. Reid (vice-chairman), J. I. Case farm machinery dealer, Lynchburg, Va., and McNeil Marshall (secretary-treasurer), associate agricultural engineer, Virginia Agricultural Experiment Station. A third vice-chairman, J. E. Collins, agricultural engineer, Appalachian Electric Power Co., was not present when the picture was taken.

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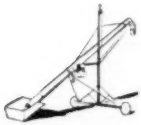
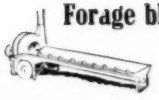


Grain loaders



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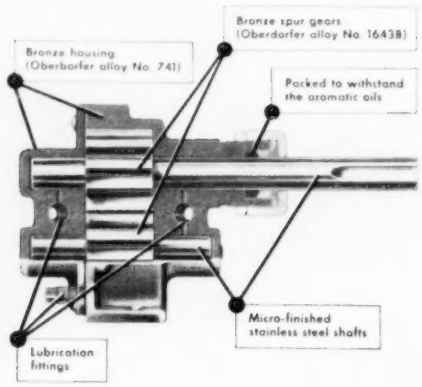

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from cornstalks by A. C. Dale, Purdue University. M. L. Esmay, University of Missouri, and Henry Giese, Iowa State College, will present a joint paper on factors affecting wind resistance and durability of asphalt shingles. The subject of pole construction for farm buildings will be discussed by F. C. Fenton, Kansas State College, and the final number on the program deals with concrete dry-wall construction of farm buildings and will be presented by R. G. Johnson of the Marietta (Ohio) Concrete Corp.

With A. H. Hemker, vice-chairman of the Division, presiding, the program for Wednesday forenoon, June 18, will open with J. W. Martin, University of Idaho, discussing farm electrification demonstrations for 4-H clubs. Demonstration equipment designed for teaching is the subject of a talk by G. E. Henderson, University of Georgia. H. L. Kugler and R. I. Lipper will discuss "Kansas College of Kilowatt Knowledge". The final number on this program is a discussion by L. I. Koontz, Appalachian Electric Power Co., on the how and why of vocational teacher training.

As stated above, there will be a joint Farm Structures and Rural Electric program on the forenoon of June 17.

The program for the forenoon of June 18, with D. B. Poor, vice-chairman, Farm Structures Division, presiding, will have as its first item the subject of sanitizing practices in quality milk production to be discussed by Dr. W. H. Haskell, Klenzade Products, Inc. This will be followed by M. L. Esmay and A. H. Groff, University of Missouri, who will discuss the relation of farm dairy housing to animal health. The requirements for quality milk production will be presented by C. J. Fenzau, Doane Agricultural Service. The closing number on the program will deal with the subject of requirements and regulations of the revised Public Health Service milk ordinance and code, to be presented by W. R. McLean of the Kansas City district of the U.S. Public Health Service.

SOIL AND WATER PROGRAM

The program for the forenoon of June 16, with R. R. Poynor, chairman, Soil and Water Division, presiding, will open with a discussion of seeding and fertilizing small grains, grasses and legumes in unprepared seedbeds by A. T. Hendrix, Tennessee Valley Authority. Clarence Bunch, U.S. Soil Conservation Service, will talk on mechanical methods of establishing range and pasture grasses, and the subject of conservation machinery practices in the Southeast will be discussed by John H. Carreker of the Soil Conservation Service. The final number on the program will deal with the functional performance of a new direct-connected plow in contour operation by Richard W. Bushmeyer, J. I. Case Co.

The session on the forenoon of June 17, with G. E. Ryerson, vice-chairman, Soil and Water Division, presiding, will have as its first subject a twenty-year appraisal of engineering practices at the Bethany (Missouri) Experimental Farm by D. D. Smith, U.S. Soil Conservation Service, following which Walter E. Selby, Kansas State College, will discuss the reclamation of flooded lands in the river valley of Kansas. Soil and water management under the complete watershed program will be the subject of a paper by Howard Matson, U.S. Soil Conservation Service. For the final number on this program, R. P. Beasley, University of Missouri, will deal with the characteristics of farm ponds as affected by topography and design.

R. R. Poynor, division chairman, will preside at the session on the forenoon of June 18, at which the opening number will be a talk on a laboratory for teaching soil and water courses by Ralph C. Hay, University of Illinois. A joint paper by F. B. Hamilton, U.S. Soil Conservation Service, and J. F. Schrunk, University of Nebraska, will deal with an analytical evaluation of application efficiencies in gravity vs. sprinkler irrigation. The third and final number on this program will be a discussion by C. J. Francis, U.S. Soil Conservation Service, dealing with drainage work in the Red River Valley of North Dakota.

New Officers of ASAE Southwest Section

EUGENE C. BUIE was elected the new chairman of the Southwest Section of the American Society of Agricultural Engineers at the regular yearly meeting of the Section held April 11 and 12 at Texarkana, Tex. He succeeds F. W. Schroeder. Mr. Buie is zone conservationist, Soil Conservation Service, U.S. Department of Agriculture, of Region 7 with headquarters at Fort Worth, Tex.

The new vice-chairman of the Southwest Section is Price Hobgood, professor of agricultural engineering, A. & M. College of Texas, College Station.

At the same meeting, A. H. Gray, Jr., head, rural development department, Southwestern Gas and Electric Co., Shreveport, La., was elected the new secretary-treasurer of the Section.

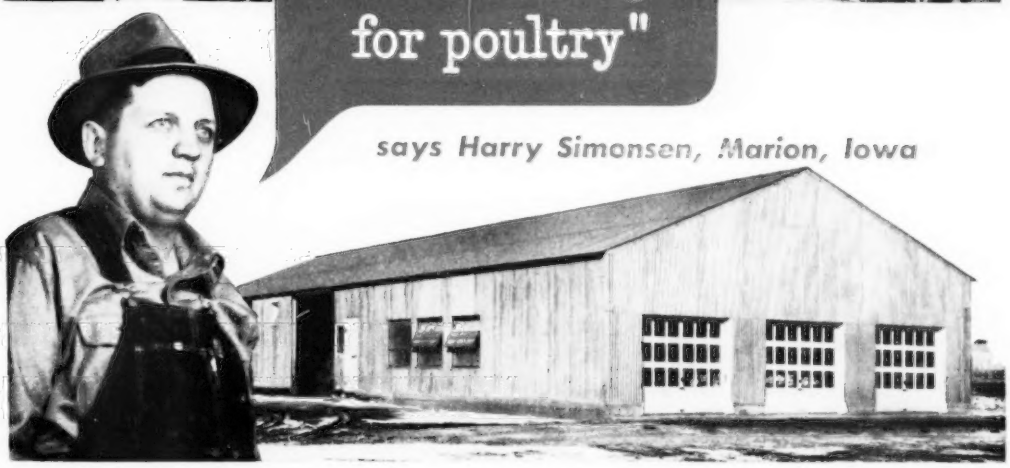
Hawaii Section Meets

SLIDES and a movie effectively illustrated a talk by Robert A. Duncan, agricultural engineer, Hawaiian Sugar Planters Assn., on sugar cane hauling and harvesting in Florida and Louisiana before the ASAE Hawaii Section meeting on April 9. Chairman Robert R. Owen, head, agricultural engineering department, Pineapple Research Institute, presided.

Owen demonstrated the Grether distributor for commercial fertilizers and presented data indicating laboratory performance of the machine.

"We recommend steel buildings for poultry"

says Harry Simonsen, Marion, Iowa



HARRY SIMONSEN uses two 36 ft. x 96 ft. steel structures as combination poultry house and machinery storage buildings. Half of each unit is used for poultry. Here's what Mr. Simonsen says about these steel buildings:

"We think these buildings make a good combination because they are easily converted if needed for other uses. For chickens, they're working fine, and are much better than our frame buildings because they are insect and vermin-proof. We don't have any trouble with paint peeling and the buildings always look good. We would recommend these steel buildings for poultry anytime."

It's easy to see why the best poultrymen are buying steel buildings. They keep out rats and are not affected by termites. The tough steel sheets are wind and rain-tight and easy to maintain.

To insulate and inside finish these versatile and durable buildings, you first apply any suitable insulating material, cover with a vapor barrier and then attach the galvanized steel sheets. The steel sheets are far better than fibrous material because hens can't peck holes in them and they are easy to keep clean and free of vermin. Ceilings are easy to insulate, too. In this case, Mr. Simonsen just stretched wire fabric overhead and covered with straw.

Steel buildings have been thoroughly proved on thousands of farms for poultry, livestock, machinery and crop storage. Ask any farmer who has a steel building and he'll be quick to tell you, *you get more for your money when you build with steel.*

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Applicants for Membership

The persons listed below have applied for admission to membership or for transfer of membership grade, in the American Society of Agricultural Engineers. Members of the Society who wish to commend or object to any of these applicants should write the Secretary of the Society at once.

ARNDT, JAMES F.—Junior stress engineer, materials engineering dept., Deere & Co., Moline, Ill.

BARTON, LEWIS W.—Owner, Lewis W. Barton Co., Haddonfield, N. J.

BRABHAM, PAUL C.—2000 Ruth St., Leesville, La.

BRACEWELL, SEARLE G.—Assistant product specialist, grass machines division, International Harvester Co., Chicago, Ill.

FARROW, FRANCIS A.—Designer, MacMillan & Bloedel, Ltd., Vancouver, B.C., Canada.

FULPER, JOHN H.—Chief engineer, Kewanee Machinery & Conveyor Co., Kewanee, Ill.

GARY, W. MIKE—District manager, The Massey-Harris Co., Chamblee, Ga.

HABAN, JOSEPH—Chief engineer, Madison Plow Co., Boscobel, Wis.

HARRINGTON, RICHARD F.—District engineer, Bearings Co. of America, Lancaster, Pa.

HOSODA, YOSHIMI—Student, University of Idaho, Moscow, Idaho.

JACKSON, TERRY L.—Senior agricultural engineer, Alabama Power Co., Birmingham, Ala.

JACKSON, WILBUR N.—Agricultural engineer, Big Creek Ranch, Encampment, Wyo.

KERR, LARRY B.—Student, University of Idaho, Moscow, Idaho.

KRASCHNEWSKI, MELVIN W.—Design engineer, John Deere Harvester Works, East Moline, Ill.

KRAUSE, ERNEST G.—Student, University of Idaho, Moscow, Idaho.

LARSEN, DARRELL C.—Student, University of Idaho, Moscow, Idaho.

MACKAY, RICHARD S.—Serviceman, farm machinery div., Gailey & Roberts, Ltd., Nairobi, Kenya, Africa.

MCPHERSON, WALTER K., JR.—Senior project engineer, New Idea Div., Avco Corp., Coldwater, Ohio.

MADDISON, LAURENCE B.—Consulting CPA, Scotland Neck, N. C.

MATUKAS, JOHN J.—Sales engineer, Fafnir Bearing Co., New Britain, Conn.

MORRELL, T. H.—Chief engineer, The Oliver Corp., Charles City, Iowa.

MORRISSEY, RICHARD P.—Assistant product specialist of dairy equipment, International Harvester Co., Chicago, Ill.

OHEIM, CURT L.—Vice-president, product development, Deere & Co., Moline, Ill.

OURADA, MARTIN J.—Student, University of Idaho, Moscow, Idaho.

PRYOR, REGINALD R.—District sales engineer, John Bean Div., Food Machinery and Chemical Corp., Lansing, Mich.

RENFROE, COMER J.—Manager, agriculture development division, South Carolina Electric & Gas Co., Charleston, S. C.

ROBISON, WAYNE L.—Student, University of Idaho, Moscow, Idaho.

SATHASIVAMPILLAI, R.—Special farm manager, Department of Agriculture, Ceylon.

SCHAAF, HENRY W.—Experimental engineer, The Oliver Corp., Springfield, Ohio.

SEARLES, WILLIAM G.—Designer, New Holland Machine Div., The Sperry Corp., New Holland, Pa.

SMOKER, ISAAC Z.—Partner, Smoker Farm Elevators, Intercourse, Pa.

STARK, MARTIN—Sales engineer, Esso Standard Oil Co., New York, N. Y.

STIVERS, OTWELL O.—Farm electrification advisor, Mississippi County Electric Co-operative, Blytheville, Ark.

STOCKER, THOMAS W.—Draftsman, Cornwall Street Railway Light & Power Co., Ltd., Cornwall, Ont., Canada.

STOLL, EMIL—Field engineer, J. I. Case Co., Racine, Wis.

STUELAND, HAROLD M.—Project engineer, John Deere Spreader Works, East Moline, Ill.

STYNER, WENDELL A.—Student, University of Idaho, Moscow, Idaho.

TOMLINSON, BYRON R.—Irrigation engineer, Soil Conservation Service, USDA, Laramie, Wyoming.

WAYLAND, WILLIAM E.—Manager of field sales, agricultural original equipment div., Dayton Rubber Co., Chicago, Ill.

WHISENANT, DEWEY A.—Trainee, product engineering, J. I. Case Co., Anniston, Ala.

WILLIAMS, LAMAR—Student, University of Idaho, Moscow, Idaho.

YORK, BRUCE O.—Tire engineer, U.S. Rubber Co., Detroit, Mich.

TRANSFERS OF MEMBERSHIP GRADE

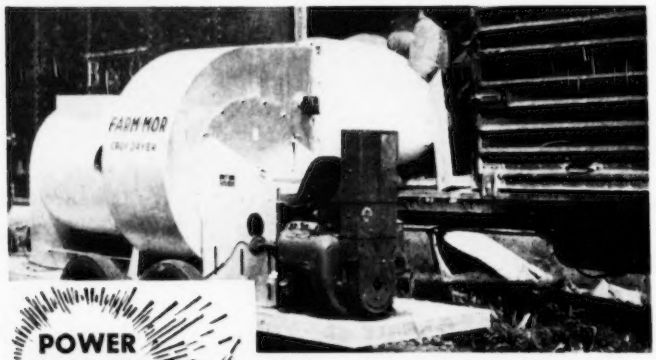
KIRKPATRICK, WILLIAM M., JR.—Engineer, U.S. Mutual Security Agency, Washington, D.C. (Affiliate to Associate Member)

MEIER, ROBERT H.—Senior engineer, John Deere Des Moines Works, Des Moines, Iowa (Associate Member to Member)

ROTH, FRED W.—Assistant professor of agricultural engineering, University of Maine, Orono, Me. (Associate Member to Member)

WARDLE, N. J.—Assistant professor of agricultural engineering, Iowa State College, Ames, Iowa (Affiliate to Member)

WINN, PAUL N., JR.—Assistant professor of agricultural engineering, University of Maryland, College Park, Md. (Associate Member to Member)



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Crops like corn, peanuts, rice, oats, soybeans, hay, grass seed and many others . . . all are dehydrated by the Farm-Mor Crop Dryer, built by Southwest Industrial Heating Engineers and powered by a Wisconsin Heavy-Duty Air-Cooled Engine.

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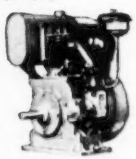
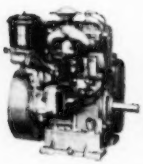
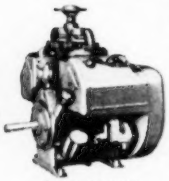


Single cylinder 6 to 9 hp. models.



2 cylinder 7 to 13 hp. models.



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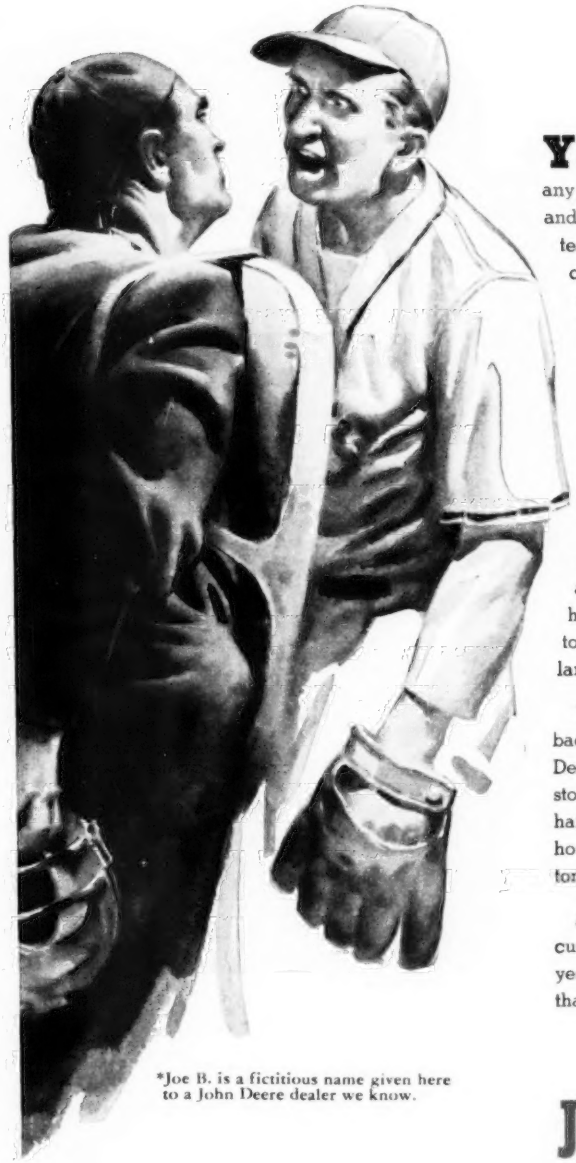
The double life of Joe B.*



*Joe B. is a fictitious name given here to a John Deere dealer we know.

YOU should watch Joe work sometime. Pick any holiday afternoon when it's summer and sunny and the Mayville Mules are out to kick holes in a team from one of the neighboring towns. You can't miss him. You'll see him out there, big and dark blue and trimmed in self-confidence. He'll be calling them as he sees them—dishing out justice like a Solomon and sticking to his decisions like Horatius at the bridge.

Naturally, competition gets a little sharp sometimes and an occasional exception is taken to Joe's uncompromising edicts. You'd think some of the names he gets called would raise welts, but they roll off Joe like rain. He can stare a shaking fist straight in the knuckles and bat down a dirty look with a flick of one heavy eyebrow. And he does it. But it's only fair to say that on those particular days, Joe's popularity snuggles mighty close to zero.

The next morning, it's a different story. Joe is back at his regular job, selling and servicing John Deere equipment. His ball-park officiousness is stored in the closet with his umpire's cap, and the hand that counted off strikes less than twenty-four hours ago stops work only to greet arriving customers.

And it's a funny thing—some of those very customers are the guys that yelled the loudest yesterday. Yep, it's a funny thing, all right—but that's America for you.

JOHN DEERE

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NEW BOOKS

PRINCIPLES OF WEED CONTROL, by Gilbert H. Ahlgren, Glenn C. Klingman, and Dale C. Wolf. Cloth, vii + 368 pages, 5½ x 8½ inches. Illustrated and indexed. John Wiley and Sons, Inc. (440 Fourth Ave., New York 16, N. Y.; London, Chapman and Hall, Ltd.) $5.00.

This is a broad approach to the weed problem in various crops, pastures, ditches and other environments, with recommendations as to control of specific weeds by cultural practices, chemicals, burning, and other methods. Related equipment is discussed briefly. Chapter headings are: Introduction, principles of control and eradication, chemicals used in weed control, physiological effects of herbicides, field crops grown in rows, small grains and flax, grasslands and rights-of-way, drilled and broadcast legumes, vegetables and fruits, drainage and irrigation ditches, stream banks, lakes, and ponds, turf, lawns, and ornamental plants, brush and undesirable trees, soil sterilants, defoliation, poisonous weeds, special wood problems, and application equipment.

FORESTRY IN FARM MANAGEMENT, by R. H. Westveld and Ralph H. Peck. (Second edition, revised by R. H. Westveld.) Cloth, xi + 540 pages, 6 x 9 inches. Illustrated and indexed. John Wiley and Sons, Inc. (440 Fourth Ave., New York 16, N. Y.; London, Chapman and Hall, Ltd.) $5.00.

Of special interest to agricultural engineers, this revised text and reference includes material on new equipment and techniques for improving the economy of forestry and forest product utilization practices. Tree planting machines and portable power saws are considered as established aids to farm forestry practice. There is additional material of agricultural engineering interest on harvesting and handling of forest products, use of wood on farms, and special products. Chapters cover forest trees in a balanced agriculture, growing forest-tree crops — economic basis, growing forest-tree crops — biological basis, how to improve and perpetuate existing farm forests, how to establish new farm forests, measuring the volumes of farm-forest products, measuring volumes and growth of farm forests, making trees into the most valuable wood products, marketing farm-forest products, best use of wood on farms, management of farm forests for special products, how farm forests may aid wildlife, farm-forest plans and records and aids to owners of farm forest. The text is supplemented by appendixes on common names of trees and their scientific equivalents, habits and requirements of the more important and widely distributed tree species in farm forests in the United States, some damaging forest insects and diseases, log rules, sample volume tables, examples of analyzing data for farm-forest plans, farm-forest financial records, federal forest experiment stations and state agricultural experiment stations.

FARM POWER, by the late Ben D. Moses and K. R. Frost. Cloth, xii + 484 pages, 6 x 9 inches. Illustrated and indexed. John Wiley and Sons, Inc. (440 Fourth Ave., New York 16, N. Y.) $5.75.

This is a text for a one-semester course for college students in agriculture. It is also suitable for use as a reference by dealers, sales, service, and operating personnel who may not have had advanced engineering training. It deals with internal-combustion power as developed in stationary engines and tractors, and makes no attempt to cover electric motors as farm power units. Chapters cover farm power development and utilization, fundamental terms relating to heat engines, engine parts, internal-combustion engine principles, valve and engine timing, cylinder arrangements, fuels and combustion, carburetion and carburetors, ignition methods, diesel engines, fundamentals of electric ignition, electric cells, electric spark ignition, magneto ignition, starting and lighting systems, governors and governor controls, engine cooling, lubrication, bearings and bearing lubrication, engine troubles, tractor types, clutches, transmissions, differentials and final drives; pulley attachments, power take-offs, and power lifts; tractor controls, air cleaners, spark arresters, traction members, engine and tractor repair, power measurement, tractor and engine testing, hitches and drawbars, and tractor selection and management.

SOIL ENGINEERING, by M. G. Spangler. Cloth, ix + 458 pages, 6 x 9 inches. Illustrated and indexed. International Textbook Co., (Scranton, Pa.) $6.50.

A reference for the many engineers and contractors with little or no formal training in soil mechanics and related matters, who encounter soil as a factor to be considered as a supporting foundation for structures, roads, airport runways, piling, dams, conduit and other high weight loads; as an engineering material in works such as earth dams, levees, and embankments; and as a factor influencing the behavior of water. Chapters cover introduction, the origin and nature of soil, the soil profile, soil structure and texture, soil density, soil surveying and sampling, soil water, hygroscopic moisture and the colloidal fraction, capillary water, gravitational water and seepage, flow nets and seepage forces, soil-water consistency, engineering soil classification, frost action in soil, granular soil stabilization, thickness of flexible pavements, stress distribution in soil, consolidation and settlement of structures, shearing resistance and strength, stability of slopes, embankments, levees, earth dams; pressure on retaining walls, bearing capacity, piles and pile-driving formulas, and underground conduits.

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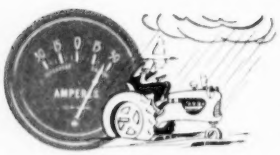

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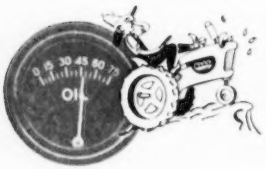

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NEW BULLETINS

The Silting of West Frankfort Reservoir, by J. B. Stall, et al. Report of Investigation No. 12, 1951, department of registration and education, State Water Survey Division (Urbana, Ill.). Extensive study of silting in this municipal water supply reservoir suggests the need of additional soil holding treatment on its watershed.

Irrigation in Illinois, by W. J. Roberts. Report of Investigation No. 11, 1951, department of registration and education, State Water Survey Division (Urbana). A report of water use indicating that irrigation in Illinois now represents only 0.0005 per cent of the combined municipal and industrial use and does not compete for water with those uses. One conclusion is that there are areas in the state where intensive development of irrigation could seriously tax available water resources.

A Summary of Weather Conditions at East Lansing, Michigan, Prior to 1950, by W. D. Baten and A. H. Eichmeier. Michigan Agricultural Experiment Station (East Lansing) unnumbered bulletin (December, 1951). Presents cumulative weather information as an aid in the interpretation of data from agricultural research and as a background for recommendations to farmers. Data summarized include air and soil temperatures, precipitation, snowfall, wind velocity, relative humidity, sunshine, solar radiation, evaporation and sublimation, length of growing season, and cumulative heat units.

Farm Water System Installation, by Elwood F. Oliver, Iowa Rural Electric Cooperative Assn. (Des Moines). Material from a variety of sources is selected, compiled, and presented in a manner calculated to be especially suited to the in-service training of electrification advisers.

Electricity on Farms in Eastern Washington, by Henry H. Stippler. Washington Agricultural Experiment Station (Pullman) Stations Circular No. 149 (July, 1951). An economist's report of rural electric progress in a specific area. It is attractively presented in 8½ x 11-inch size with a green cover and printed in green ink throughout which may contribute to its readability.

Electric Brooding, by D. W. Teare. Farmers' Bulletins 2039 (1952). U.S. Department of Agriculture (Washington 25, D.C.). This applies especially to pig and lamb brooding, emphasizing recognized good practice and its advantages.

Electric Light for the Farmstead, by Elizabeth Beveridge and Albert V. Krewatch. Farmers' Bulletin No. 1838 (Revised November, 1951). U.S. Department of Agriculture (Washington 25, D.C.). A practical guide to wiring requirements for good lighting, selection of lamps and fixtures for various locations and purposes, lighting for farmyards and buildings outside the home, and special purpose lamps.

Methods and Equipment for Harvesting Ladino Clover Seed, by Geo. B. Hanna, W. H. Sheldon, and W. M. Carleton. Reprint from the Quarterly Bulletin of the Michigan Agricultural Experiment Station (East Lansing) Vol. 34, No. 3 (February, 1952). Reports on a comparison study with results generally favorable to a vacuum-type harvester.

How to Improve Engineering-Management Communications. National Society of Professional Engineers (1121 Fifteenth St., N.W., Washington 5, D.C.). Single copies $2.00. This is a report on Executive Research Survey Number One by the sponsoring Society's Professional Engineers Conference Board for Industry. It summarizes in 46 pages the results of a study of a representative cross section of industrial organizations in the United States. The study was made by questionnaire, supplemented by personal inquiry and consultation. Phases of the subject covered in separate chapters are: The lines of industrial communication—who participates, how management gets the opinions of its engineers, what engineers want to know about management policy, the media of engineering management communication, developing management potential in trained engineers, and how to improve communications. A list of suggested readings on communications is appended. It is indicated that reports to follow on related surveys by the same Board will cover "How to Improve the Utilization of Engineering Manpower," "How to Attract Qualified Engineers," and "How to Train Engineers in Industry."

Some Tests of Jacketed Space Heaters for Heating Small Farm Dwellings, by Carl A. Reaves and R. E. Stewart. University of Missouri (Columbia) Research Bulletin 486 (November, 1951). Jacketed heaters, together with fans and duct systems, show some possibilities of improving heat distribution and fuel economy.

The Grassland-Livestock Handbook. Joint Committee on Grassland Farming (Box 30, Norwich, N.Y.). Single copies 25 cents, sliding scale of prices on quantity orders. Special imprinting and back cover available at nominal cost on orders of 1000 or more. This is a companion booklet to the Committee's earlier publication, "Green Fields Are Gold." It is a 48-page pocket-size publication giving brief specific answers to 104 questions on grass and legume programs, how to cash in through livestock, best usages for pasture, hay, silage, fodder, and roughage crops, irrigated pastures, processing and storage facilities, and grassland machinery. Concluding recommendations are brief and to the point: (1) Use good quality livestock to make grassland farming profitable, and, (2) don't plunge into grassland farming. Grow into it.

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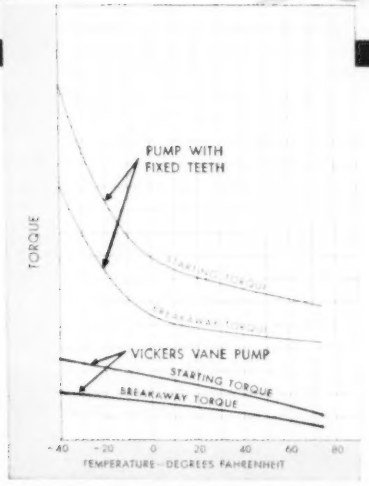

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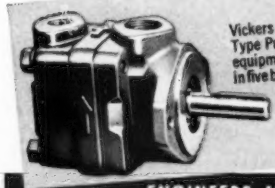

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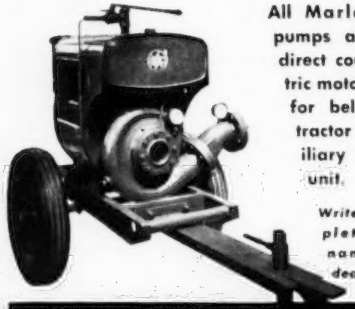

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PERSONALS OF ASAE MEMBERS

Buford M. Cannon, who recently received his master of science degree in agricultural engineering at Virginia Polytechnic Institute, has joined the agricultural engineering staff at North Carolina State College as a research assistant professor. Born and reared on a peanut farm in South Georgia, he has been doing research work in the field of artificial drying and curing of peanuts at VPI. In his new work he will be engaged on research problems involved in peanut mechanization.

Lawrence E. Creary has resigned as assistant agricultural engineer, Louisiana Agricultural Experiment Station, to accept a position as engineer in the experimental station of the Grasselli Chemicals Dept., E. I. du Pont de Nemours & Co., at Wilmington, Del. He has been assigned to the department's formulations group and is engaged in an investigation of engineering and equipment problems. The recently expanded formulations group contains one chemical and one agricultural engineer and is an expression of the Company's continual effort to produce formulations and agricultural chemicals that are easily and effectively applied in conventional application equipment.

Wesley A. Harper has joined the staff of the Taylor-Wharton Iron and Steel Co., Cincinnati, Ohio, in the capacity of research engineer. He was formerly chief engineer of the National Farm Machinery Cooperative of Bellevue, Ohio. In announcing Mr. Harper's addition to the staff, H. E. Cragin, Jr., director of research and development in the Taylor-Wharton organization, indicated that it is a step in a program of development to improve the company's service to its railroad and industrial customers for fabricated steel.

W. J. Liddell, until recently sales manager of Sunset Engineering Co., has been transferred to Memphis, Tenn., where he has been made vice president and general manager of the Southern Irrigation Co., an associated company. The new company will fabricate and distribute portable irrigation systems in the states of the Southeast.

Stanley W. McBirney, until recently in charge of the weed control machinery development project of the farm machinery division (BPISAE), U.S. Department of Agriculture, is now associated with the Cooperative Fiber Commission, which is a cooperative Point 4 project or mission between the Cuban government and the USDA. His work will deal with the mechanization of harvesting and processing of kenaf, a soft fiber being developed as a substitute for jute in making sugar bags, etc. He is headquartering at the American Embassy in Havana.

William E. Meek, in charge of the regional cotton mechanization project, under the joint sponsorship of the U.S. Department of Agriculture and the Mississippi Agricultural Experiment Station at Stoneville, has resigned to enter the farm machinery business at Greenville, Miss. Mr. Meek has made distinct contributions to the mechanization of farm crops of the South, including the development of the line-diagram system of setting farm machinery. He is the author of numerous articles on crop mechanization and has served on many ASAE and other committees dealing with farm machinery problems.

C. P. Wagner has been named electric farm consultant for North Central Electrical Industries, 209 Foshay Tower, Minneapolis, Minn. He was formerly director of farm service for the Northern States Power Co., a position he had filled since 1925. Previous to 1925 he had worked in the latter's distribution and engineering department on the design of farm service lines. In his new work he will have a large part in a rural electrification promotion program to be expanded by the NCEI, a trade association of electrical manufacturers, distributors, contractors, dealers, and utilities.

At a dinner honoring him, on his recent retirement as head of the agricultural engineering department at Pennsylvania State College for the past 36 years, Prof. R. U. Blasingame (left) is shown receiving from Howard Miller (center), president of the Pennsylvania Student Branch of ASAE, a combination electric desk lamp and clock as a gift from the Branch. Dr. Lyman E. Jackson (right), dean of agriculture of the College, was the speaker for the occasion.

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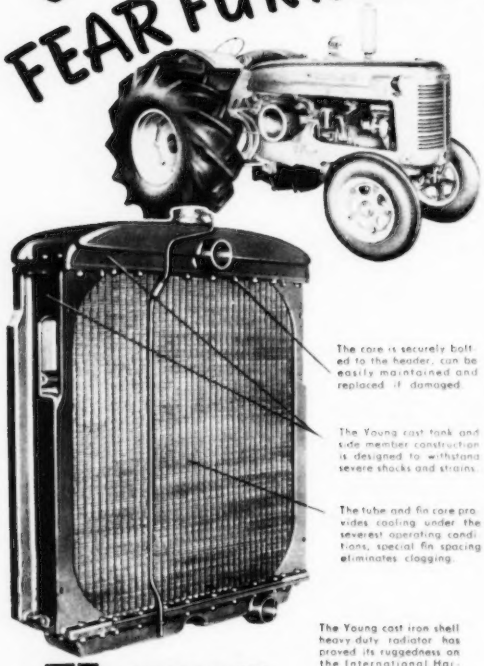

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Physiological Aspects of Chick Brooding

(Continued from page 308)

Management. The same authors (1949b) report a series of brooding experiments to eighteen days in which all conditions except heat and placement of feed and water were the same. In one lot no hover was used and the temperature of the entire room was 94 F on the first day and reduced 0.8 F each day. Feed and water were readily available at all times to the chicks. The second lot was raised in a commercial battery brooder under which the temperature was started at 94 F and lowered 0.8 F per day while the ambient temperature was kept at 75 F for the entire period. The feed and water were so arranged that they were essentially inside the battery. The third lot was similar to the second except that feed and water were obtained by the chicks reaching through holes along the sides of the battery. In the fourth lot the chicks were brooded on the floor in a room held at 75 F and had access to electric hovers under which the temperature was managed as in the second and third series. Water was provided by small chick founts and feed was in chick feed troughs on the floor outside the hover.

At the end of the eighteen-day experiment, the results were as follows:

Type of brooding	Lot	Gain in weight per chick, g	Feed eaten in 18 days, g	Feed efficiency
Uniform environment	(1)	88.0	220	0.40
Brooder, feed inside	(2)	76.6	196	0.39
Brooder, feed outside	(3)	65.6	177	0.37
Floor	(4)	54.8	152	0.36

A further study of their data revealed the fact that the chicks in lot 1 began eating earlier than those in the other lots. Lot 2 was second in this respect followed by lots 3 and 4 in that order.

Practical Considerations. These data supply the agricultural and heating engineers with some of the information they deem desirable in planning brooder houses and equipment. At the same time, some information is yet lacking. The authors determined, but did not report, the volume of water in the cloacal excreta. The total would increase as the birds grew and, with the increased volume of respiratory water increase the moisture in the litter. This in turn furnishes an improved habitat for the development of harmful fauna and flora. It is a disease hazard.

Thus while the humidity, in the experiments reported by Barott and Pringle, had no effect on their birds to eighteen days, it is of great importance in practice, especially after the birds are three weeks old.

A corollary of this damp litter problem is another for which there is no information the engineers can set on their numerical "scoot sticks". How much ventilation will be required by a given number of birds to keep the litter dry enough to hold the disease hazard to a minimum, remove the ammonia from the pen and still not unduly dissipate the heat? Dougherty and Moses (1933) found that one cubic foot of air per 100 chicks per minute under a closed electric brooder was not sufficient to prevent excessive condensation or meet the needs of the chicks to six weeks *(Continued on page 314)*

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Physiological Aspects of Chick Brooding

(Continued from page 312)

of age. Two cubic feet of air per 100 chicks per minute met their needs as well as larger amounts but failed to keep the litter dry after they were three weeks old. Four cubic feet of air failed to keep the hover dry to six weeks of age. On the other hand, one of the chief objections of in-the-floor heating systems has been the excessive dryness of what little litter could be used.

This problem is further complicated by the fact that certain feeds (Wheeler and James, 1950) will increase the amount of water eliminated in the droppings.

Dukes (1942) points out that the observed ill effects of poor ventilation are rarely due to either a lack of sufficient oxygen or an overabundance of carbon dioxide, but to heat stagnation. He stated: "A high environmental temperature depresses radiation, high humidity limits evaporation, and lack of movement of air limits both because an envelope of warm, moist air tends to form around the bodies of the individuals in the poorly ventilated quarters."

SUMMARY

1. While millions of chicks are successfully brooded each year, only a few precise studies have been made of their general physiology during that stage.

2. The temperature at which minimum metabolic activity occurs decreases gradually from 94-95 F for the day-old chick to 70 F for the one-year-old pullet.

3. Maximum feed efficiency is obtained at approximately the same temperatures as minimum metabolism.

4. Chicks of all ages are more susceptible to increases in temperatures than to decreases.

5. Water of respiration is quite constant at temperatures of minimum metabolism but rises rapidly at higher temperatures.

6. The humidity of the environment under the experimental conditions did not affect the chick's growth to eighteen days of age.

7. Relative accessibility of feed and water are important factors in starting chicks properly.

8. In practical operations, a knowledge of the total amount of moisture voided by a given number of birds at various ages would be desirable in order to plan ventilating systems.

9. The ventilating system should be designed to keep the litter reasonably dry, remove ammonia and not unduly dissipate the heat.

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Popular for most types of mobile equipment. Quickly adjustable forward or backward with a flick of the adjusting lock-handle. Full-comfort roomy cushion seat and restful padded back. "No-Sag" synchronized action springs. Foam rubber or sisal and cotton. Artificial or genuine black cowhide.
many other styles
MILSCO JUNIOR
NO. 811
NEW MILSCO "UTILITY"
NO. 244
HAND EASE
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FORE AND AFT ADJUSTMENT LEVER
Simple Adjustment Fore and Aft
MILSCO MANUFACTURING COMPANY
2732 N. 33rd STREET
Famous in Seating
MILWAUKEE 45, WIS.

MACHINES THAT HELP *YOU* PROMOTE BETTER FARMING

COMBINE HARVESTING PUTS THE STRAW BACK ON THE LAND . . . IMPROVES THE SOIL

Not only does combine harvesting save labor — it also helps save the soil. By returning the straw to the ground in a thin, even blanket, soil structure and fertility are improved. Erosion is reduced.

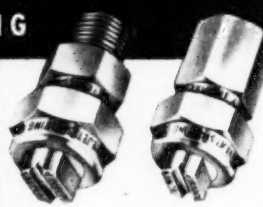
The fertilizer value alone of wheat straw left on the land is from $10 to $18 per acre at present prices. Add to this its value in improving soil structure, retaining moisture and reducing erosion and you can see that combine harvesting is of tremendous value in helping save our big natural resource — soil.

The Massey-Harris Company is proud of its leadership in pioneering the Self-Propelled combine that opened a new era of economy and efficiency in grain harvesting . . . in developing the original straight-thru full width combine that put the combine on the diversified farm, both of which have contributed so much to saving time, labor, grain — and soil . . . and making the farm more productive, the farmer more prosperous.

Make it a Massey-Harris

EVERY AGRICULTURAL ENGINEER HAS A STAKE IN SOIL CONSERVATION

SPRAY NOZZLES FOR BETTER, FASTER FARM SPRAYING



TEEJET performance features

- Super precision orifice tips . . . DRILLED and MILLED for uniform spray and exact volume control.
- Interchangeable orifice tips . . . in every type and capacity from one gallon per hour and up.
- Eleven different spray angles from 8° (solid stream) to 150°.
- Unconditionally guaranteed for performance as specified.
- Factory inspection and test of all nozzles and tips before shipment.

The investment a farmer makes in chemicals, equipment and time will dependably produce a profit when TeeJet Spray Nozzles are installed on the spray boom. TeeJet nozzles are precision made to provide the best in performance from both equipment and chemicals. Proved by test in every type of farm spraying. For complete information, write for Bulletin 58 . . . the comprehensive reference manual for farm spray nozzles, strainers and fittings.

SPRAYING SYSTEMS CO.
3226 RANDOLPH ST. • BELLWOOD, ILLINOIS
Write for Bulletin 58

SPRAYING SYSTEMS TeeJet SPRAY NOZZLES

SISALKRAFT WATERPROOF SISAL REINFORCED PROTECTIVE PAPERS

Farmers have proved SISALKRAFT provides dependable protection

For over 20 years many uses of SISALKRAFT Products on the farm have proved this tough, waterproof protective paper is worthy of your highest endorsement. Write for complete information on ALL farm uses of SISALKRAFT and SISALATION.

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Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this bulletin the following listings still current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated:

POSITIONS OPEN—1951—OCTOBER—O-401-544. DECEMBER—O-473-550, 480-551. 1952—JANUARY—O-484-553. FEBRUARY—O-503-556, 502-557. MARCH—O-537-558, 552-560, 559-561, 576-562. APRIL—O-594-563, 592-564, 596-565, 584-566, 602-567, 603-568, 610-569.

POSITIONS WANTED—1951—OCTOBER—W-391-78. DECEMBER—W-459-81, 464-82, 454-84. 1952—FEBRUARY—W-504-92, 528-95, 529-96. MARCH—W-511-97, 525-99, 538-100, 542-102, 560-103, 566-104, 573-105, 564-106. APRIL—W-588-107, 590-108, 592-109, 612-111.

NEW POSITIONS OPEN

RESEARCH FELLOWSHIP in agricultural engineering-irrigation, for work in conjunction with project on tobacco irrigation, in a state college in the Southeast. BS deg in agricultural engineering or equivalent with grade average of B or better. Good worker with initiative, enthusiasm, and genuine interest in research, particularly in irrigation, plus usual personal qualifications for advanced study and research. Appointment for 2 yr to complete MS deg in agricultural engineering. Greater part of research work applied to thesis problem. Salary $1200 for 10-mo period. Possibility of additional employment at extra pay for remaining 2 mo. O-619-570

EXTENSION AGRICULTURAL ENGINEER for soil conservation work in district of several counties in an eastern state. Work is with county agents, farmers, and rural organizations and will include a limited amount of general agricultural engineering. BS deg in agricultural engineering. Farm background essential. Some experience preferred. Usual personal traits for public service positions. Good opportunity for advancement. Age 25-30. Salary open. Expense account. O-623-571

MANAGER, tractor and farm implement appraisal guide manual published annually. Midwest location. Market survey and manufacturer contact by mail. Dealer background desirable. Must be suited to desk work. Opportunity for advancement into truck and auto appraisal field. No age limit. Salary $5000. O-630-572

NEW POSITIONS WANTED

DESIGN, development, or research in power and machinery in industry or public service, preferably in Southwest. BS deg in agricultural engineering, 1949, Texas A. & M. College. General farm background. Two years as farm operator. Farm implement and tire sales 8 mo. War enlisted service in Army Air Corps 8 mo. Single. Age 24. No disability. Available on two weeks' notice. Salary open. W-608-112

TEACHING, research, design, development, or writing in power and machinery, with manufacturer or public service agency, in South, Southwest, or Pacific Coast Area. BS deg 1950, MS deg 1951, Louisiana State University. Instructor in agricultural engineering while working on MS deg. Since June 1951 junior engineer on detail and assembly design and drafting with aircraft manufacturer. Previous experience as merchant seaman, postal clerk, and U.S. storekeeper-gauger. War enlisted service in Coast Guard Reserve over 3 yr. Married. Age 40. No disability. Available on reasonable notice. Salary $4800. W-604-113

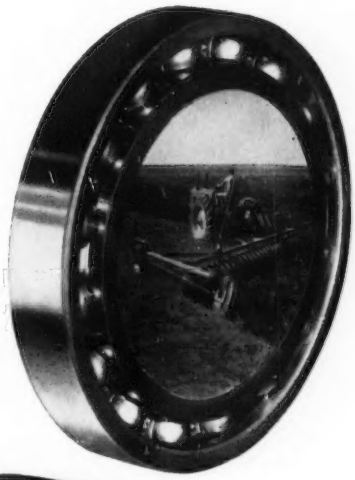
EXTENSION, teaching, or research in rural electrification with industry or public service in Southeast or Southwest. BS deg 1948, MS deg 1949, in agricultural engineering, University of Georgia. Farm background. Agricultural engineer with R.E.A. 26 mo. Currently regional agricultural engineer. War enlisted service in Naval Reserve over 3 yr. Married. Age 30. No disability. Available on reasonable notice. Salary $4800. W-626-114

DEVELOPMENT, service or writing in power and machinery with industry or public service in mild or warm climate location. BS deg in agriculture, 1941, agricultural engineering 1948. Since 1948, experimental engineer on development of tractor and implement hydraulic systems and testing to determine effective use combinations and methods with tractors and various implements. War commissioned service in Navy over 3½ yr. Married. Age 34. No disability. Available on reasonable notice. Salary open. W-629-115

SALES or development in power and machinery field with private industry. Any location. BS deg in agricultural engineering, 1952, Southern Louisiana Institute. Summer employment experience in surveying, inspecting and as sampler assistant to superintendent in cotton oil mill. Part time employment in school as laboratory assistant in agricultural engineering department. War service in Infantry nearly 2 yr. Married. Age 23. No disability. Available June 1. Salary open. W-601-116

No conversion problem ...

in these dual-purpose plants

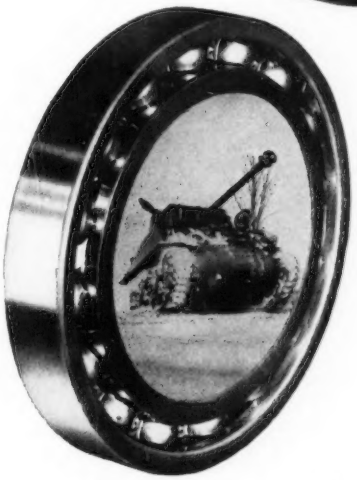


Jig borers and jets, trucks and tanks, household appliances and electronic instruments, all use New Departure ball bearings of the same materials, same heat treatment, the same methods of precision manufacture.

Thus conversion from one to the other in New Departure's three great plants is largely a matter of changing the emphasis on types and sizes.

The capacity of the world's largest ball bearing plants is your assurance of the best possible production schedules.

New Departure's engineers and vast resources for research are freely at your disposal.



North Side Bristol group are "guns-and-butter" plants.

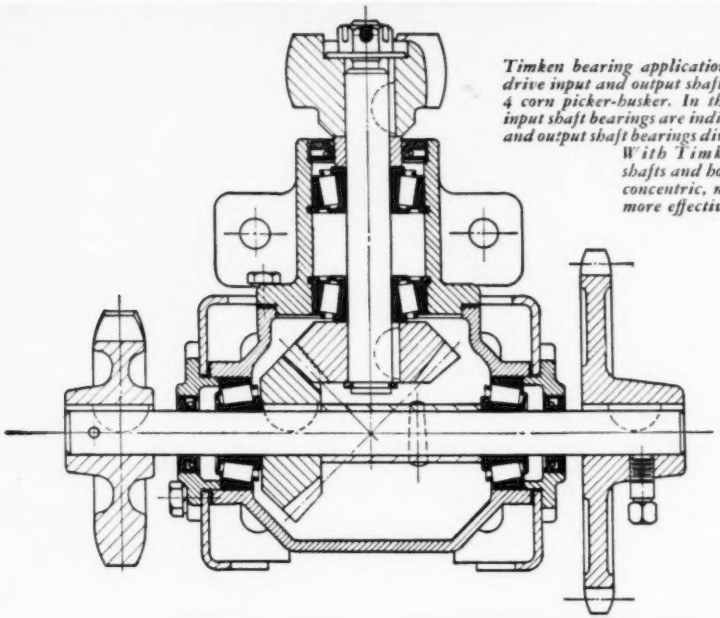
Nothing Rolls Like a Ball...

NEW DEPARTURE

BALL BEARINGS

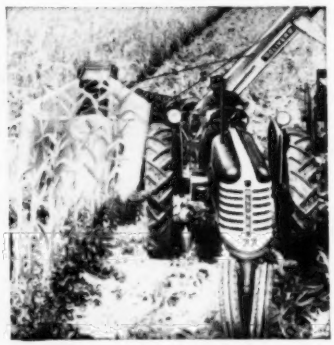
NEW DEPARTURE • DIVISION OF GENERAL MOTORS CORPORATION • BRISTOL, CONNECTICUT

EVERY NEW FARM TRACTOR HAS TIMKEN BEARINGS; MORE AND MORE IMPLEMENTS ARE USING THEM, TOO!



Timken bearing application on the main drive input and output shafts of Oliver No. 4 corn picker-husker. In this application, input shaft bearings are indirectly mounted and output shaft bearings directly mounted. With Timken bearings, shafts and housings are kept concentric, making closures more effective.

How Oliver engineers design corn picker drive for once-a-season lubrication



WHEN designing the main drive for their No. 4 corn picker-husker, Oliver engineers wanted to provide for once-a-season lubrication. That meant using bearings that would take combination loads and make bearing closures more effective. So Oliver mounted the main drive input and output shafts on Timken® tapered roller bearings.

Timken bearings take radial and thrust loads in any combination, hold shafts in accurate alignment. They keep shafts and housings concentric, making closures more effective. Lubricant stays in and dirt stays out. The main drive of the picker-husker can go an entire season without change or addition of lubricant.

With Timken bearings, three of the biggest design problems facing implement engineers are solved at once — (1) dirt, (2) combination loads, and (3) ease of operation. Implement users are assured of longer implement life, less chance of breakdown on the job, less frequent lubrication, higher towing speeds.

For more information, write for your copy of "Tapered Roller Bearing Practice on Current Farm Machinery Applications". The Timken Roller Bearing Company, Canton 6, Ohio. Cable address: "TIMROSCO".

The farmer's assurance of better design →

Tapered Roller
TIMKEN BEARING
EQUIPPED

NOT JUST A BALL ○ NOT JUST A ROLLER ▭ THE TIMKEN TAPERED ROLLER ▭ BEARING TAKES RADIAL ▯ AND THRUST ▯ LOADS OR ANY COMBINATION